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Analysis of Alaska Transportation Sectors to Assess Energy Use and Impacts of Price Shocks and Climate Change Legislation

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Abstract

This project analyzed the use of energy by Alaska's transportation sectors to assess the impact of sudden fuel price changes. We conducted three primary types of analysis: (1) Development of broad energy use statistics for each transportation sector, such as estimated total annual energy and fuel use, carbon emissions, fuel use per ton-mile and passenger-mile, and cost of fuel per ton-mile and passenger-mile. (2) Economic input-output analysis, which estimates the employment and output of air, rail, truck, and water transportation sectors in the Alaska economy. (3) Adjustment of input-output modeling assumptions to reflect sudden fuel price changes and/or emissions taxes to estimate the potential impact of these changes on industry output and employment in the Alaska economy. We found that Alaska air transportation used approximately 1.9 billion gallons of fuel annually, of which 961 million gallons were used for intra-state and exiting Alaska flights. Water transportation (ships, barges, and ferries) used 101.8 million gallons of fuel annually, with approximately 84.3 million gallons for intra-state and exiting segments. Railroad transportation used 5.1 million gallons of fuel annually, and truck transportation used 8.8 million gallons of fuel annually. The impact of fuel price increases similar to those that occurred between 2008 and 2010 results in an estimated $456.8 million in value-added losses to the Alaska economy through cost increases of transportation services. The cost increases, or equivalent loss in income, to Alaska households are $26.8 million. A carbon emissions tax would have the greatest impact on the cost of air transportation services, followed by water, trucking, and rail.

Executive Summary

This project analyzed energy use by Alaska's transportation sectors to assess the impact of sudden fuel price changes or carbon emissions taxes. Inexpensive fossil fuels helped nurture Alaska's early economic growth. Over time, key Alaska industries such as fishing, mining, tourism, and transportation, as well as activities such as subsistence gathering, have grown to depend directly on liquid fossil fuels.

Compared with other states, Alaska is unique in its energy use. In 2010, for example, per capita energy consumption in Alaska was triple the national average. High energy use makes the Alaska economy more vulnerable to energy price volatilities and shocks. For state policy makers and industry, such vulnerability necessitates a better understanding of how energy prices and legislation affect transportation patterns and efficiency.

The relationship of transportation to greenhouse gas (GHG) emissions is also important in the context of ongoing social and political discussion of climate change. Transportation is a major contributor to the GHG emissions (primarily carbon dioxide, CO_2) associated with increased global temperatures; almost 30% of U.S. GHG emissions come from transportation. Additionally, transportation assets and operations worth billions of dollars are vulnerable to the impacts of climate change. Freight GHG is growing at a rate three times that of passenger GHG.

We conducted three primary types of analysis:

(1) Development of broad energy use statistics for each transportation sector. We estimated the energy and fuel used by the air, water, trucking, and rail transportation sectors. We compared their fuel intensity to move passengers and freight by estimating their passenger-miles per gallon of fuel, ton-miles per gallon of fuel, fuel costs per passenger-mile and per ton-mile, and CO_2 emissions per ton-mile and passenger-mile.

(2) Economic input-output analysis, to estimate the employment and output of air, rail, truck, and water transportation sectors in the Alaska economy.

(3) Adjustment of input-output modeling assumptions to reflect sudden fuel price changes and/or emissions taxes (which function similarly to an increase in fuel prices) to estimate the potential impact of these changes on industry output, employment, and Alaska households.

We analyzed the impact of fuel price changes that occurred in 2008 and, by examining income, employment, and industry output changes in 2010, how the Alaska economy, in the long run, adjusted to higher prices and potential price volatility.

We estimated that rail is the most efficient form of transportation for moving freight per gallon of fuel, followed by barge, marine ship, truck, and ferry. In the lower 48 water transportation is consistently found to be most fuel efficient; Alaska water transportation may be less efficient than rail because of the less than full back-hauls over long distances. As measured by passenger-miles per gallon of fuel, we again found that rail transport is the most fuel-efficient, followed by air and ferry. Fuel costs per ton-mile and passenger-mile followed the same pattern of efficiency (Figures ES1 and 2), as well as CO_2 emissions intensity (Figure ES3). Note that ferries provide essential transportation services to locations not connected by roads. Given the age and configurations of Alaska ferries, the policy of avoiding direct competition with the private sector, and the schedules operated to meet the needs of the traveling public, it is unlikely that ferries could ever be as fuel-efficient as their private sector counterparts are.

Faced with continued high or increasing fuel prices or carbon legislation, the demand for Alaska Railroad transportation services could potentially increase with shifts away from trucking. However, because the distance from Anchorage to Fairbanks and the Kenai Peninsula are relatively short, freight handling would have to be quite efficient, and wages competitive, to compete with the comparative efficiency of truck transportation, with its fewer freight intermodal transfers.

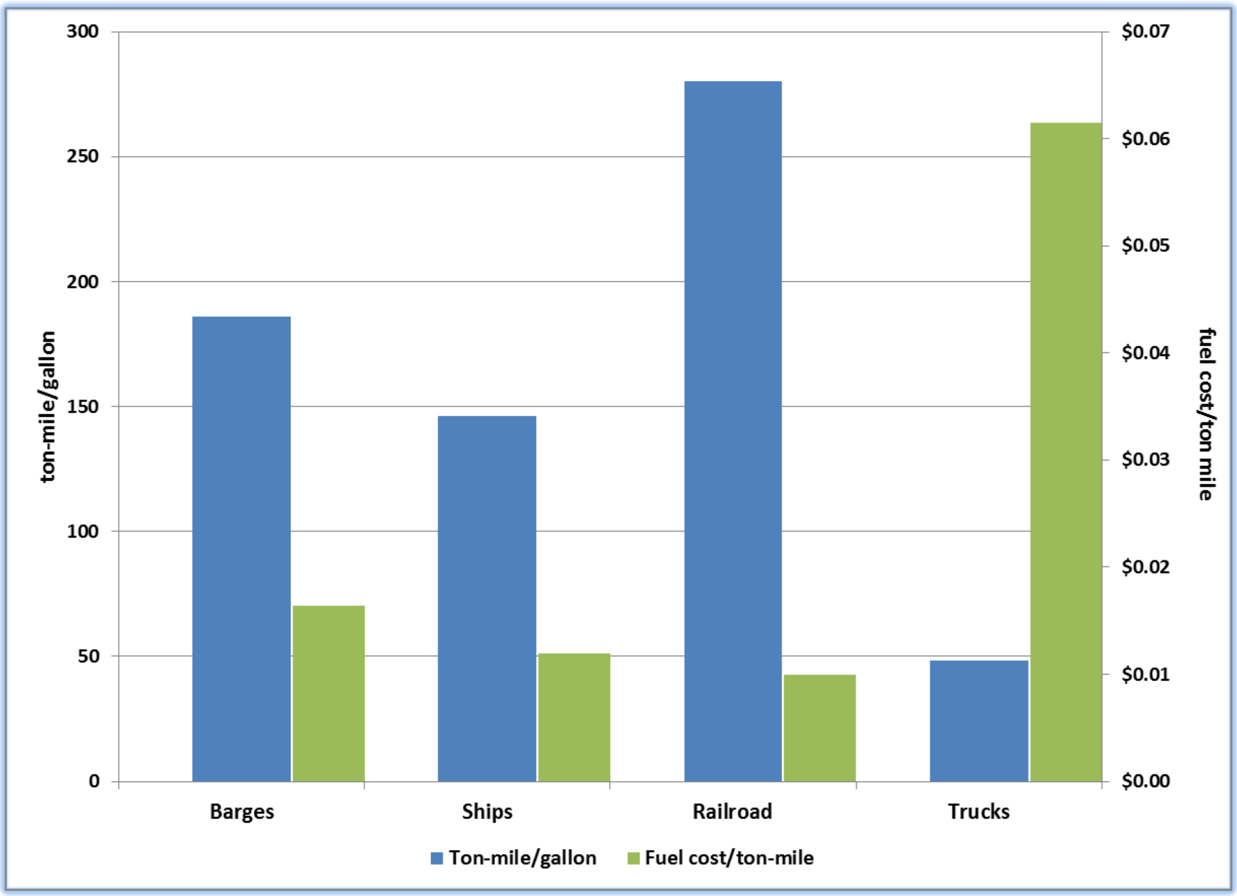
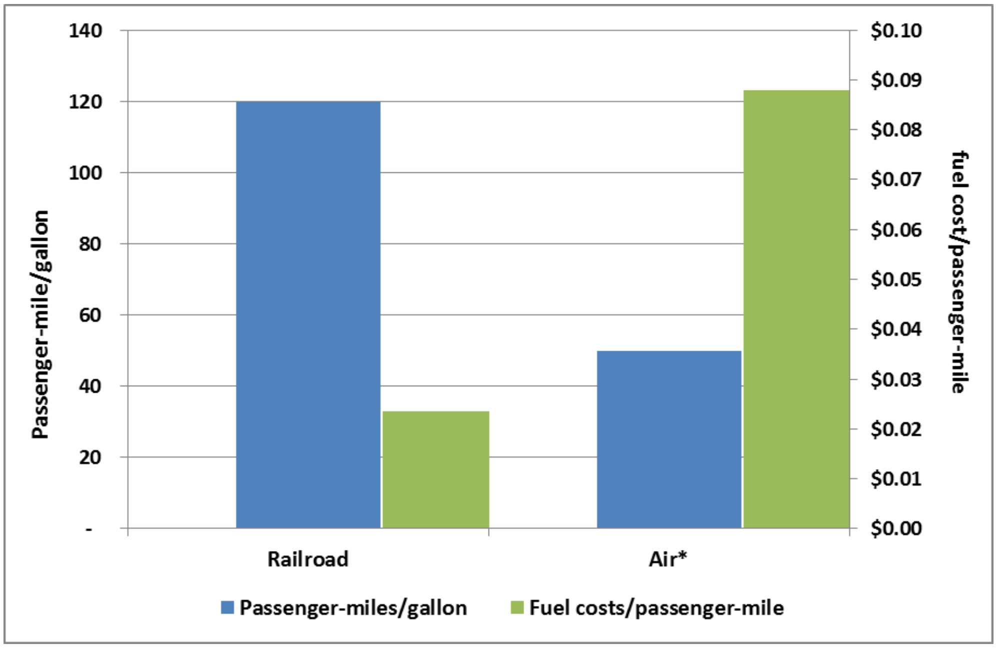


Figure ES1. Comparison of fuel use and costs per ton-mile for Alaska transportation, 2007–2010, 2011$
(Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Waterborne Statistics; AMHS; AKRR; IFA; company proprietary information; author calculations)



*U.S. average for comparison purposes only.

Figure ES2. Comparison of fuel use and costs per passenger-mile for rail and air, 2007–2010, 2011$
(Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Army Corps of Engineers, Waterborne Statistics; AMHS; AKRR; IFA; Ingram, 2008; company proprietary information; author calculations)

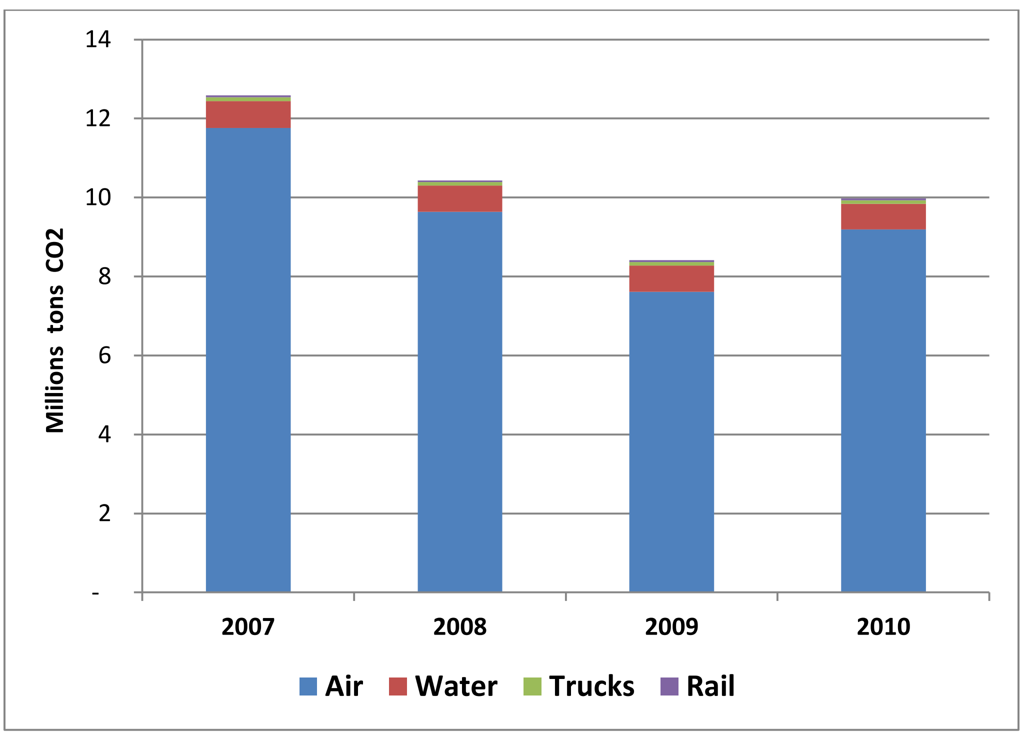


Figure ES3. Comparison of annual emissions by transportation sector, intra-state and exiting only, 2007–2010
Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Waterborne Statistics; AMHS; AKRR; IFA; company proprietary information; author calculations.

To connect fuel price-related changes in transportation costs to impacts on the Alaska economy, we examined several factors, including industry and household transportation uses. Analysis of the Alaska economy found that the ten industries most dependent on transportation services are:

1. Seafood product preparation and packaging
2. Support activities for oil and gas operations
3. Transport by truck
4. Drilling of oil and gas wells
5. Construction of new nonresidential commercial and health care structures
6. Construction of new residential single-/multi-family housing
7. Electric power generation, transmission, distribution
8. Mining of gold, silver, and other metal ore
9. Food services and drinking places
10. Other state and local government enterprises

Consequently, these industries are the most affected by increases in fuel prices or other changes that raise the cost of transportation services as an input in their production. Most of these are core industries in the Alaska economy.

The ten Alaska industries that would be most affected by carbon emissions legislation are:

1. Petroleum refineries
2. Natural gas distribution
3. State and local government electric use
4. Asphalt paving mixture and block manufacturing
5. State and local government passenger
6. Other basic chemical manufacturing
7. Transport by pipeline
8. Plastics material and resin manufacturing
9. Commercial fishing
10. Transport by air

Because of the fuel and carbon intensity of air transportation, airlines have made a sustained effort to improve air transportation efficiency with increased load factors and increased fuel efficiency of airplanes. However, despite the increases in fuel efficiency, of the four transportation sectors analyzed, air transportation continues to be the most vulnerable to emissions legislation impacts.

These ten industries potentially most affected by carbon emissions legislation are also the industries where increased efficiencies and reduced dependence on fossil fuels could have the most payback, as measured by avoiding potential emissions tax impacts.

Alaska households at all income levels are also vulnerable to increases in the price of transportation services as a result of fuel price increases or carbon emissions legislation. Transportation services include the direct purchases of things like passenger tickets for air, rail, or ferry tickets as well as the embedded costs of transportation services in groceries or furniture. If Alaska households continued to purchase transportation services at the same level after fuel price increases similar to those that occurred between 2008 and 2010, these services would cost an additional $26.8 million; an estimated 73% of these cost increases would be paid by households earning over $50,000 annually. In all likelihood, however, households would reduce their spending on transportation services. Water and truck transportation services declined the most in our simulation, probably because the majority of goods Alaska households routinely purchase are transported by water and truck.

In addition to the higher cost of transportation services resulting from higher fuel prices, direct purchases of refined petroleum products would cost Alaska households an additional $124.1 million if the households continued to purchase at the same level after fuel price increases similar to those that occurred between 2008 and 2010. Similar to price increases for transportation services, households with incomes of $50,000 or higher would absorb an estimated 70% of the refined petroleum price increases.

A recent National Cooperative Freight Research Program (NHCRP) report (Holguín-Veras, José, et al, 2013), found that there is a lack of freight cost data for the various modes of freight transportation, and that no single source can provide the key cost data for any mode. In most cases, some data are available in the reports published by public-sector agencies, trade groups, and research universities. However, because these data were collected in response to the needs of specific projects, they cannot replace data formally collected as part of regularly scheduled data collection efforts. Publicly available cost data for air freight and terminals are practically nonexistent. Unfortunately, no single data source could fill all the gaps in freight cost data. Our data collection efforts and analyses were hampered by this data issue.

Our economic impact simulation did not include utilities, so price increases for space heating and electricity are not included in these estimates.

Introduction

Inexpensive fossil fuels helped drive Alaska's early economic growth. Over time, key Alaska industries such as fishing, mining, tourism, and transportation, as well as activities such as subsistence gathering, have grown to depend directly on liquid fossil fuels including diesel, gasoline, and jet fuels. In addition, Alaska's urban service economy has depended heavily on a relatively low cost of living, facilitated by low energy prices in Southcentral Alaska, and doing business has historically been assisted by cheap transportation fuels.

These conditions are changing rapidly and perhaps permanently. Although Alaska has a low absolute energy demand compared with the U.S. average, its per capita energy consumption is the highest in the country—more than three times the U.S. average (U.S. DOE, EIA, 2012a). A number of factors contribute to the state's higher per capita energy consumption. Alaska's role as a major world air cargo and transportation hub, oil producer, and marginal refiner substantially increases the per capita use calculation. Alaska's remoteness and dispersed populations, along with a limited road system, cause Alaskans to depend more on air transportation services. The relatively greater dependence of Alaska industries and residents on energy creates a higher vulnerability to energy price volatilities and shocks. Such vulnerability means that state policy makers and industry need to better understand how energy prices and legislation affect transportation patterns and efficiency. Transportation is a major contributor to greenhouse gas (GHG) emissions—almost 30% of U.S. GHG emissions—associated with increased global temperatures, and transportation assets and operations worth billions of dollars are vulnerable to the impacts of climate change (TRB, 2012a, b). Freight transportation GHG is growing at a rate three times that of passenger transportation GHG (TRB, 2012b).

This project analyzed the use of energy by Alaska's transportation sectors to assess what might happen if fuel prices suddenly change. We conducted three primary types of analysis:

(1) Development of broad energy use statistics for each transportation sector, such as estimated total annual energy and fuel use, carbon emissions, fuel use per ton-mile and passenger-mile, and cost of fuel per ton-mile and passenger-mile.

(2) Economic input-output analysis, which estimates the employment and output of air, rail, truck, and water transportation sectors in the Alaska economy.

(3) Adjustment of input-output modeling assumptions to reflect fuel price shocks/changes and/or emissions taxes to estimate the potential effect of these changes on industry output and employment in the Alaska economy.

We analyzed the impact of fuel price changes that occurred in 2008 and, by examining income, employment, and industry output changes in 2010, we analyzed how the Alaska economy adjusted to higher prices and potential price volatility in the long run.

The report is organized into background, research approach, and findings and applications sections, each of which is organized by transportation mode—water, rail, trucking, and air. The findings and applications section is organized by transportation mode, fuel use, economic impact analysis, and emissions.

Background

Given its geography, Alaska has long relied on aviation and marine transportation to move people and goods (Figure 1). Freight transport for goods used in Alaska continues to be dominated by marine transportation, as has been the case since Russian colonization (Gray and Rowe, 1982). Although Alaska is the largest state by area, its road mileage is the fifth lowest in the nation, leaving 82% of its communities unconnected to a state road system (Schultz, 2012). The reasons for Alaska's limited road system are many, and the state's unusual dependence on efficient intermodal transportation will no doubt continue. Extreme weather, rugged terrain, vast distances, low population density, and scattered islands make future road construction initiatives for connecting communities to the road system difficult and extremely costly when compared with the number of end users (ADOT&PF, 2008). Residents of these rural areas not connected to the state's road system primarily use expensive air transportation for passenger and consumer goods movement.

In more populated areas, intermodal reliance looks quite different. More than half of the state's population resides within the "Railbelt," the region served by the Alaska Railroad (AKRR) and the state highway system. This region and a few small urban areas in Southeast Alaska have competing transportation modes, services, and economies of scale for freight and passengers. The major changes in Alaska's transportation system in the last 50 years have primarily been technological improvements within each transportation mode rather than major system changes.

From an economist's perspective, understanding Alaska's highly intermodal transportation system requires a focus on inputs and outputs that are specific to that system, especially energy resources. The journey of freight goods to Alaska consumers offers a good illustration. Most of the food, household, and consumer goods shipped to Alaska from the continental United States begin their journey at manufacturing plants or distribution facilities. Trucks or trains then transport the goods to ports in either Tacoma or Seattle, Washington, where they are loaded onto container ships, barges, or roll-on/roll-off vessels for shipment to Alaska ports. If bound for a community connected to the highway system, the freight often completes its journey in trucks. Freight also travels north via the Alaska Railroad. Freight destined for towns off the road system is flown from either Anchorage or Fairbanks to remote communities and then is either driven by pickup truck if there is a regional road system or loaded onto smaller aircraft or boats for shipment to outlying villages. Quite often in remote areas, freight makes the final leg of the journey in sleds pulled by snow machines or on four-wheelers (ADOT&PF, 2008) (Figure 2). Each leg of this journey involves a specific mode and energy resource—nearly always liquid fuel.

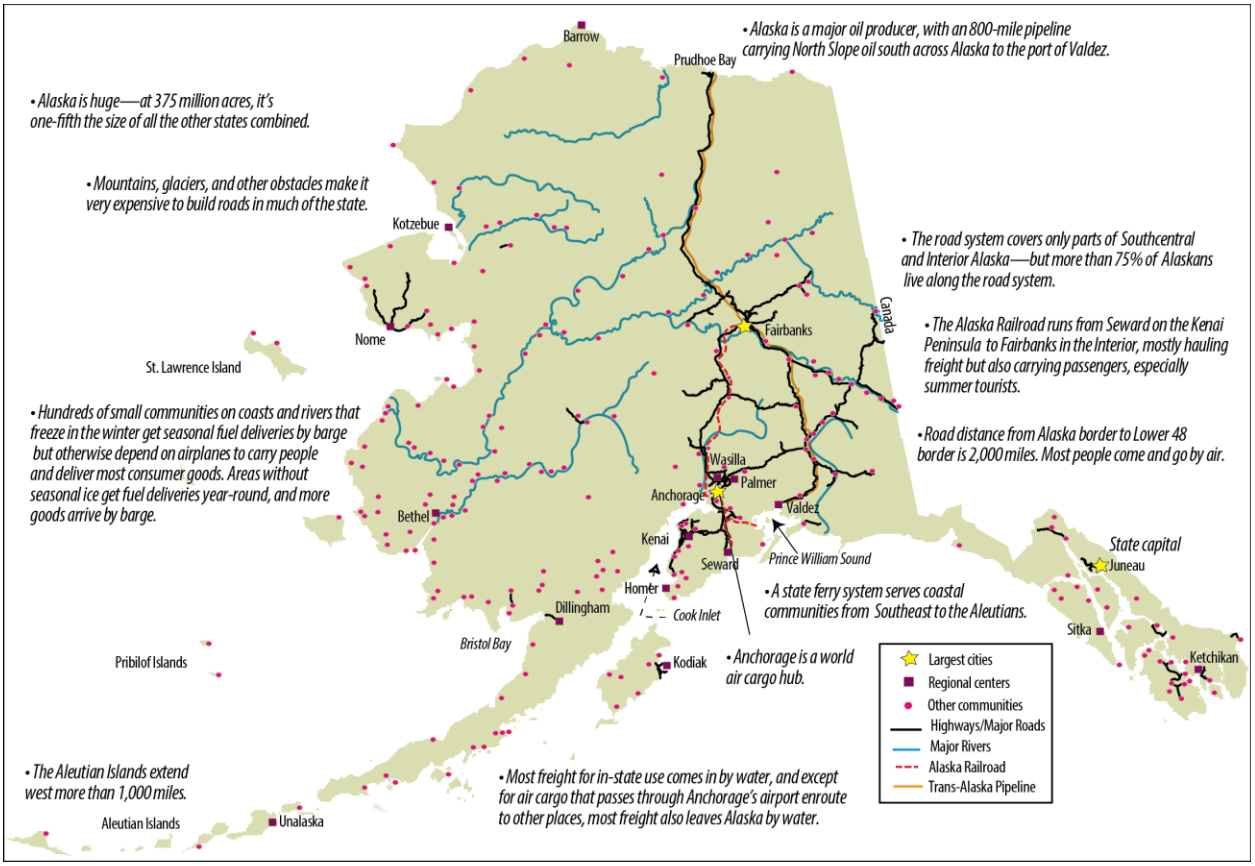


Figure 1. Alaska transportation system

Figure 2. Passenger delivery in Grayling (Photo credit: S.G. Colt)

Alaska's Transportation Modes

Water Transportation

Alaska depends more heavily on water transportation than does any other state in the continental U.S. Water transportation is one of the smaller transportation sectors as measured by employment, but it handles the greatest tonnage of freight entering Alaska. Access to navigable water has been a critical factor in Alaska's development, often to the extent of dictating the location of communities. Even the Interior community of Fairbanks owes its existence to its location on the Chena River. At 33,900 miles, the shoreline of Alaska is far greater than that of the entire Lower 48. Commercial shippers serve this extensive coastline as far north as Prudhoe Bay. The Yukon, Tanana, and Kuskokwim Rivers and some of their tributaries also are important shipping routes for nearby communities (Fried and Keith, 2005).

Ports and harbors within coastal and riverine communities are an integral part of the freight transportation network. Ports are involved in the transport of forest products, oil and bulk petroleum, coal, seafood, general cargo, and consumer goods. While overland trucking and rail are important for delivery within the state, marine and air transport dominate Alaska's interstate freight movement (ADOT&PF, 2008). There are approximately 476 public and private ports and harbors in Alaska—240 in the southeast region and 236 in the southwest and western regions combined. This figure does not include barge landing and boat haul-out facilities along the riverine communities of the Kuskokwim and Yukon Rivers.

The Port of Anchorage (POA) is Alaska's major port. Annual cargo entering the POA—most of it originating at the Port of Tacoma—accounts for an estimated 90% of the merchandise used by Alaska communities west of Cordova (UAA, 2011). Shipments bound for Alaska are nearly 30% of Tacoma's total cargo activity. The value of these goods is estimated at well over $1 billion annually (Chase, 2004).

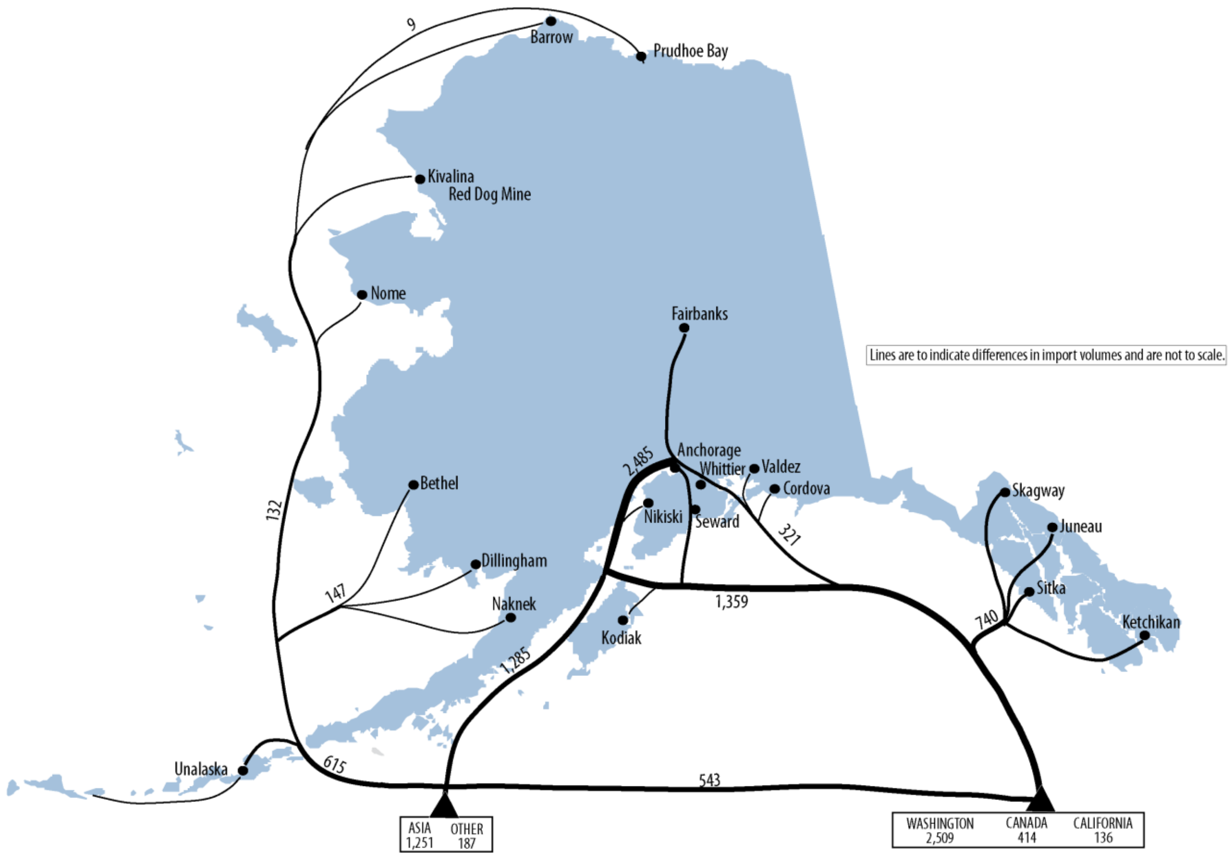
The POA is also a major distribution point for liquid fuels. On average, two-thirds of the fuel for air carriers at Ted Stevens Anchorage International Airport, and two-thirds of the fuel used by the U.S. military and federal government agencies in Alaska are delivered through the Port. This includes 100% of the jet fuel for Joint Base Elmendorf-Richardson (UAA, 2011).

The primary types of marine transportation moving freight and passengers to Alaska include:

- Railcar barges operating from Tacoma, Washington, and Prince Rupert, British Columbia;
- Ocean vessels providing roll-on/roll-off services for highway trailers operating from Tacoma, Washington;
- Container vessels originating in Tacoma, Washington;
- Ferries operating in Southeast, Southcentral, and Southwestern Alaska; and
- Barges operating from the Pacific Northwest primarily to Southeast and Southcentral Alaska.

Key transportation providers serving this market are Totem Ocean Trailer Express (TOTE), Horizon Lines, CN AquaTrain, and Lynden Transportation. Railcar barge movements destined for the Port of Whittier, Alaska, connect with the Alaska Railroad for movement of goods to Anchorage, Fairbanks, and other inland destinations. A number of barge companies deliver goods to Southwest and Western Alaska from the Port of Anchorage or from the Pacific Northwest. In addition to fuel delivered from refineries in Anacortes, Washington, some fuel is delivered from Asia.

The majority of this capacity serves Southcentral and Interior Alaska (and to a lesser extent Southeast Alaska), accessed primarily through the Ports of Anchorage and Whittier. The Port of Whittier, while served weekly by Alaska Marine Lines barge service, is predominantly used for delivery of railcar barges via the AquaTrain connecting with the Alaska Railroad. Based on the schedule and equipment of marine transportation to Southcentral and Southeast Alaska, the estimated total freight capacity of these service providers is approximately 4.7 million short tons annually (QGI, 2006). Estimates of imports and exports by water transportation are shown in Figure 3 and Figure 4. For more information on companies shipping goods to and from Alaska, see Appendix A.



Note: Aggregate figures for imports and exports are based on the U.S. Army Corps of Engineers 2010 Waterborne Statistics, including the State Public Domain Data Base by Origin and Foreign Cargo Inbound and Outbound. Inter-waterway figures are based on author calculations using data from Waterborne Commerce of the United States (WCUS) 2010 and Foreign Cargo Inbound and Outbound data. These calculations remove double-counting intrastate traffic and reconcile differences in data. Discrepancies between inter-waterway figures and aggregate totals are attributable to the limitations on the number of ports reported and information published in WCUS.

Source: Ginny Fay, Tobias Schwörer, Mouhcine Guettabi, and Jeffrey Armagost, 2013, *Analysis of Alaska Transportation Sector to Assess Energy Use and Impacts of Price Shocks and Climate Change Legislation*, Institute of Social and Economic Research, University of Alaska Anchorage.

Figure 3. Estimate of imports to Alaska via water transportation, thousands of short tons, 2010

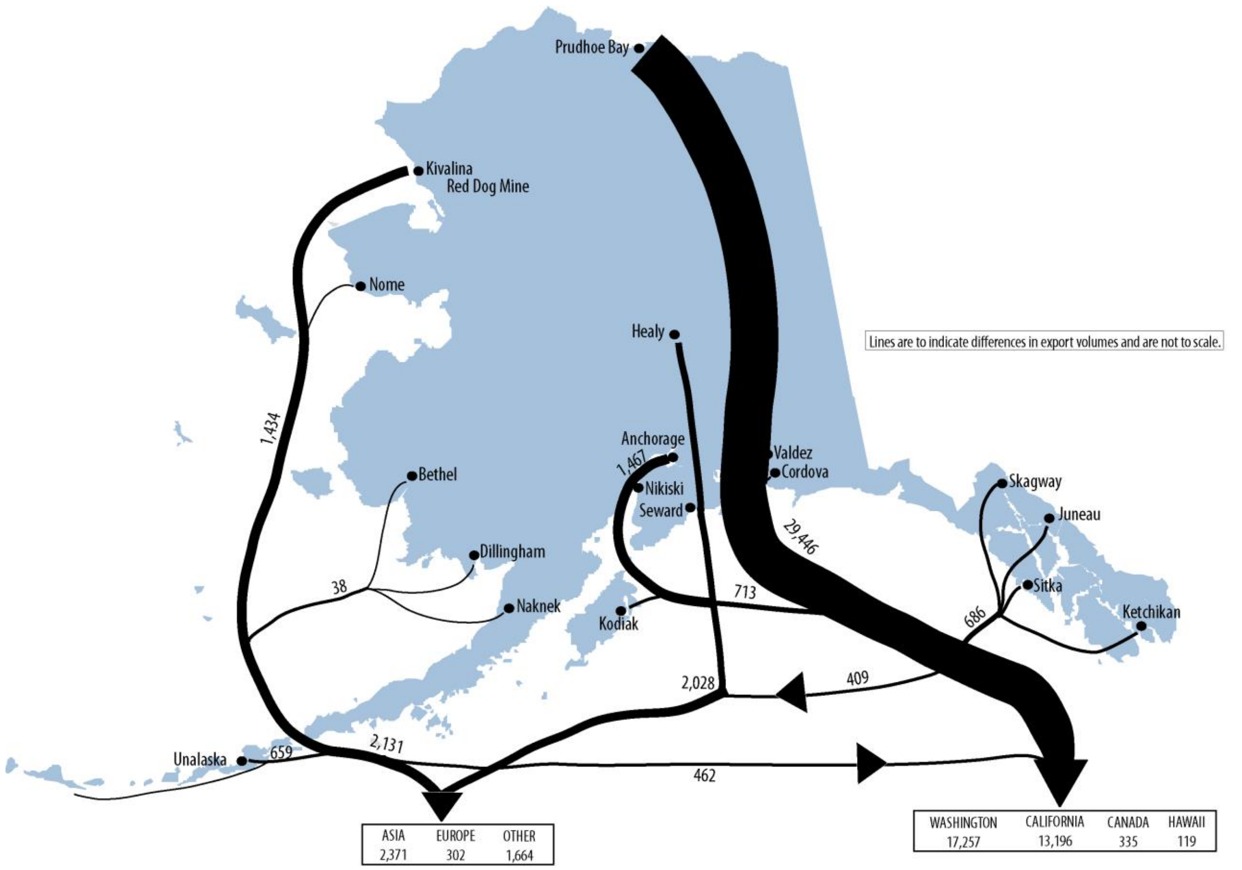


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Figure 4. Estimate of exports from Alaska via water transportation, thousands of short tons, 2010

Ferries

The Alaska Marine Highway System (AMHS) operates 11 vessels serving 32 ports that transport more than 300,000 passengers, 100,000 cars, and 3,400 freight vehicles annually. The AMHS routes stretch over 3,700 miles serving Southeast Alaska, Prince William Sound, Kodiak Island, and the Aleutian Islands (Figure 5). The AMHS plays an important role in the economies of these regions and in Alaska's transportation system (Metz et al., 2011).

The Inter-Island Ferry Authority (IFA) was formed in 1997 to improve transportation to island communities in southern Southeast Alaska. The Prince of Wales Island communities of Craig, Klawock, Thorne Bay, and Coffman Cove joined in a coalition with Wrangell and Petersburg to create the IFA; Hydaburg joined the group in 2010. The IFA is a public corporation organized under Alaska's Municipal Port Authority Act and governed by a Board of Directors.

The IFA development plan includes both the Hollis-Ketchikan and Coffman Cove-Wrangell-Petersburg passenger/vehicle ferry routes. Alaska Department of Transportation and Public Facilities (ADOT&PF) support for both routes was received in 1998. Alaska's congressional delegation secured funding for the two planned IFA vessels. The *M/V Prince of Wales* inaugurated daily scheduled round-trip service between Hollis and Ketchikan in January 2002 (Figure 6). A sister vessel, *the M/V Stikine*, provided round-trip service from Coffman Cove to Wrangell and Petersburg for three summers (2006, 2007, and 2008), but this service is now on hold. The IFA ferries currently connect with vessels of the AMHS at Ketchikan.

Figure 5. Alaska Marine Highway System communities and routes
Source: ADOT&PF, AMHS, 2012

Figure 6. Inter-Island Ferry Authority communities and routes
Source: Inter-Island Ferry Authority, 2012

Trucking

Trucking's share of transportation employment in Alaska is considerably smaller than it is elsewhere in the country. Nationwide, the trucking industry employs over a third of all transportation workers, compared with about 15% in Alaska. But the rest of the nation enjoys a vast network of interstate and secondary highways that connect most communities to the road system (Fried and Keith, 2005; U.S. DOT, 2010). Alaska is connected to the rest of the nation via the Alaska Highway, but does not have the well-developed road system of states in the Lower 48 (Figure 7). As a result, transportation by truck is a smaller portion of the transportation industry in Alaska than it is nationally (Fried and Keith, 2005). In this analysis we estimate freight movement and fuel use for Alaska long-haul trucking only; we do not estimate fuel use by local delivery trucks transporting freight. The companies that conduct these operations and the segments traveled are shown in Table 1.

Figure 7. Map of Alaska major roadways
Source: ADOT&PF, 2012

Table 1. Long-haul trucking companies providing services in Alaska

	Anchorage to:					Fairbanks to:	Alaska to:
Company	**Seward**	**Soldotna/Homer**	**Valdez**	**Fairbanks**	**SE AK**	**Prudhoe Bay**	**Lower 48/Canada**
AirLand		X	X	X		X	
American Fast Freight		X		X		X	
Bob Benson				X		X	
Carlile	X	X	X	X		X	
City Express	X				X		X
Husky Haulers							X
Lynden		X		X		X	
Midnight Sun		X		X		X	
Pacific Alaska Freightways	X	X		X			
Sourdough				X		X	
Weaver Brothers		X		X		X	
Wilson Brothers			X				

Source: Company websites

Railroads

Two railroads serve Alaska. One is the publically owned Alaska Railroad, and the other is the privately owned White Pass and Yukon Route Railroad. The Alaska Railroad is an independent corporation serving ports and communities from the Gulf of Alaska to Fairbanks (Figure 8).

The State of Alaska bought the railroad from the federal government in 1985. The Alaska Railroad is governed by a seven-member board of directors appointed by the governor of Alaska, and is mandated to be self-sustaining and responsible for all its financial and legal obligations (ADOT&PF, 2008). Alaska has 632 total railway miles—611 public miles owned by the Alaska Railroad Corporation and about 21 miles privately owned by the White Pass and Yukon Route Railroad, providing links into Canada.

The Alaska Railroad is a major part of the transportation network, both within the state and between Alaska and the Lower 48. It connects with rail service from the rest of the U. S. and Canada via its barge facilities in Whittier, and ships coal and naphtha to Asia via the Port of Seward. The railroad carries both passengers and freight, but large volumes of a variety of freight account for most of its operating revenue (Verrelli, 2012). In recent years, petroleum products hauled from the North Pole refinery to the Anchorage area have made up much of the railroad's freight revenue. The Alaska Railroad carries several hundred thousand tons of coal per year between Healy and Seward for overseas export to Asia and South America; it hauls coal from Healy to Fairbanks and a significant portion of the gravel used in the Anchorage bowl from the Matanuska-Susitna Valley. The railroad can carry these large volumes of freight more efficiently and at lower cost than trucks can (ICF International, 2009; Tuck and Killorin, 2004).

The Alaska Railroad provides passenger service to tourists during the summer season. The railroad is part of the tourist infrastructure, providing access to Denali National Park and other destinations.

The White Pass and Yukon Route Railroad is a narrow-gauge railroad that operates solely for tourism, between Skagway, Alaska, and Carcross, Yukon, each year from May to September. A wholly owned subsidiary of Tri-White Corporation based in Toronto, Ontario, the White Pass and Yukon Route generated $18.2 million in 2006, with 431,249 passenger trips (ADOT&PF, 2008). Though this railroad was originally developed to serve Yukon gold mining, and served as an ore-carrying railroad as recently as the 1970s, the owners recently expressed limited interest in resuming the railroad's ore-carrying capacity (ADOT&PF, 2008).

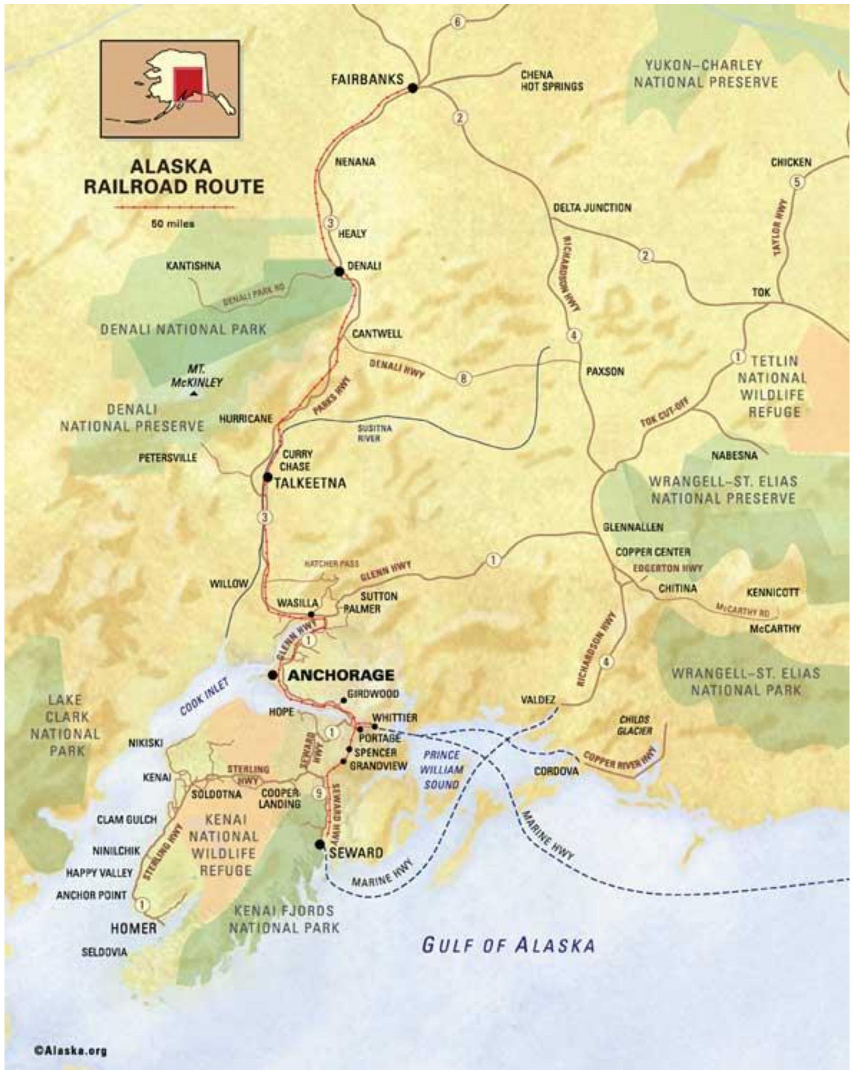


Figure 8. Alaska Railroad route map

Source: Alaska Railroad, 2012. The red line is the Alaska Railroad between Fairbanks and Seward.

Aviation

Airports, seaplane bases, and heliports located in remote geographic regions of Alaska are critical to the movement of passengers and freight within the state and to and from other national and international destinations. The *Alaska Aviation System Plan* (ADOT&PF, 2011) included an assessment of the contribution of the aviation industry to the Alaska economy (Northern Economics, Inc., 2009, 2011). The aviation industry, as defined in the statewide analysis, includes all the businesses and organizations located at an airport. Spending by these on-site entities supports local businesses and employs Alaskans for its year-round operations, contributing $3.5 billion directly and indirectly to the state's economy. This dollar amount equals approximately 8% of the state's $42 billion 2007 gross state product (GSP), a 40% higher share than the aviation industry's contribution to the U.S. economy. The analysis also estimated that the aviation industry creates more than 27,000 on-site jobs and almost 20,000 off-site jobs, which represents about 10% of jobs in Alaska—again over 40% more than the national percentage of jobs in aviation.

The primary reasons for the prominence of the aviation industry in the Alaska economy are the state's large geographic area, remoteness, and lack of connected roads. According to the 2011 *Alaska Aviation System Plan*, 82% of the communities in Alaska are not connected to a highway or road system and rely on air service to transport goods and passengers. As a result, the state has a large aviation network, with 10,000 pilots operating in 700 registered airports and 1,200 airstrips across more than three million square miles (Alaska Department of Labor and Workforce Development, Research and Analysis, 2012).

According to a 2009 economic study (Northern Economics, Inc., 2009), the average number of annual enplanements per capita for off-road communities in Alaska is 14.6, eight times higher than the number of annual enplanements per capita for even the next highest state—Idaho at 1.8—and more than 30 times higher than the lowest comparison group—Montana at 0.5 enplanements per person per year. The number of freight pounds per capita for Alaska is 39 times higher than that of rural communities in the next-highest surveyed state. Alaska communities in the study averaged 1,096 pounds of airfreight per capita in 2007, while rural communities in Oregon averaged 28 pounds. Rural communities in Montana averaged just 2 pounds of airfreight per person in 2007. Alaska, and especially remote rural communities not connected to roads, clearly depends on air to transport passengers and goods.

These transportation services are provided by 271 commercial operators in Alaska and over 10,000 licensed pilots, of which more than 2,800 are commercial pilots. Commercial carriers fly over 835,000 hours annually, including 420,000 scheduled flight hours and 415,000 unscheduled flight hours (Alaska Air Carriers Association, 2012). Alaska has a fleet of 10,947 aircraft, of which 40% are based in Anchorage and 85% are single-engine fixed wing. Anchorage records 1.6 million landings annually, including 2.8 million metric tons of cargo, making it the third highest among world airports in cargo volume (Alaska Air Carriers Association, 2012).

Research Approach

This analysis necessitated the collection of a considerable amount of proprietary data from transportation companies. To the extent possible, we collected information for the years 2006 through 2010 directly from marine shipping, barge, and trucking companies. We obtained aviation data from the U.S. Department of Transportation, Research and Innovative Technology Administration (RITA), Bureau of Transportation Statistics (BTS). We downloaded aviation data from the RITA website and used that data to estimate fuel consumption and costs by aviation fleet type (U.S. DOT, RITA, BTS, 2010).

The statistics sections of the Alaska Marine Highway System (AMHS) and the Alaska Railroad Corporation provided us with data. The Alaska Inter-Island Ferry Authority (IFA) also provided requested data. The IFA and AMHS data were the most complete data we received.

For barges and trucking, only one company in each subsector provided data. We used these data in conjunction with secondary data to model the barge and trucking subsectors.

A recent National Cooperative Freight Research Program (NHCRP) report (Holguín-Veras, José, et al, 2013, found that there is a lack of freight cost data for the various modes of freight transportation, and that no single source can provide the key cost data for any mode. In most cases, some data are available in the reports published by public-sector agencies, trade groups, and research universities. However, because these data were collected in response to the needs of specific projects, they cannot replace data formally collected as part of regularly scheduled data collection efforts. Publicly available cost data for air freight and terminals are practically nonexistent. Unfortunately, no single data source could fill all the gaps in freight cost data. Our data collection efforts and analyses were hampered by this data issue.

For each transportation mode, we attempted to estimate fuel use and cost as a total and per ton-mile and/or passenger-mile, as applicable. A ton-mile is defined as one ton (2,000 pounds) transported one statute mile. Ton-miles are computed by multiplying the net weight of the carried freight times the segment mileage for a shipment. For example, if the Alaska Railroad carries 26,280 passengers on the 112-mile Anchorage-to-Seward rail segment and uses 81,715 gallons of fuel, then the passenger-miles per gallon of fuel is 36:

$$(26{,}280 * 112)/81{,}715 = 36 \text{ passenger-miles per gallon}$$

Similarly, if the railroad moves 2,361,900 tons of gravel on the 55-mile Wasilla-to-Anchorage rail segment, using 199,164 gallons of fuel (because the cars travel empty one way), then the ton-miles per gallon of fuel is 652:

$$(2{,}361{,}900 * 55)/\ 199{,}164 = 652 \text{ ton-miles per gallon of fuel}$$

We did not include the weight of the ship, plane, train, or truck in making these estimates. However, the weight difference and fuel use intensity are reflected in the average fuel-use-per-mile statistics that we calculate. Fuel and energy use while in ports, airports, rail yards, and truck depots are not included in this analysis. Fuel use is for the transportation of freight and passengers. For each transportation mode, we also calculated total CO_2 emissions and emissions per ton-mile and/or passenger-mile (U.S. DOE, EIA, 2012b).

We converted all fuel prices to 2011 dollars using the U.S. Consumer Price Index (CPI) as reported by the Alaska Department of Labor and Workforce Development (ADLWD, 2012).

Details on each transportation sector's data and modeling are presented in the following sections. Because of the considerable differences in the data provided and the subsequent need to construct models to develop final datasets, the methods sections differ considerably in length and detail. The precision of the data also varies considerably, and readers should note the limitations of the data when using the results.

Water Transportation

Marine Ships

Marine shipping companies provided monthly data on northbound and southbound tonnage and gallons of fuel used during 2006 through 2010. One company provided monthly fuel prices per barrel, while the other provided the total annual cost of fuel. These data were used to estimate marine shipping fuel prices and to calculate ton-miles of freight moved per gallon of fuel and the cost of fuel per ton-mile. To avoid potential release of proprietary data, we present marine shipping results aggregated or as part of other water transportation statistics.

Barges

In contrast with other transportation modes where we received considerable information from a number of companies—or the data were publically available through government reporting requirements—only one barge company provided an aggregation of monthly data for the movement of freight. We used this barge company data as a prototype to construct a barge fuel-use model. We estimated fuel use for regional barge shipments by taking the number of additional barge trips by travel segments from the U.S. Army Corps of Engineers' published *Waterborne Statistics* of freight movement by port (U.S. Army Corps of Engineers, 2012a, b) and published freight schedules of barge companies serving Alaska. We used the prototype barge company's information in conjunction with U.S. Army Corps of Engineers data to estimate types of tugs and barges used and their fuel consumption per mile traveled. We made these estimates in the absence of publically available or proprietary data, but we believe they are reasonable, carefully developed estimates. Still, they are merely estimates. Details on these calculations are provided in Appendix B.

Ferries

We used annual reports of the Alaska Marine Highway System (AMHS) to estimate monthly data on northbound and southbound passengers and freight in between ports. The Inter-Island Ferry Authority also provided monthly data for 2006 through 2010. We estimated short tons of freight based on the average weight per vehicle class and the number of vehicles reported in different vehicle classes in the AMHS annual reports. Fuel cost information came directly from fuel purchase invoices. Fuel invoice information included the date and location of the fuel purchase and the receiving vessel. We allocated fuel consumption between ports based on the mileage between ports of a particular vessel port of call. Finally, we were able to estimate monthly fuel consumption and fuel cost in between ports, which was matched to the monthly vessel port-to-port data. We have used the resulting dataset to calculate ton-miles of freight moved per gallon of fuel and the cost of fuel per ton-mile for shipping by ferry, as well as passenger-mile per gallon of fuel.

Recognizing the differences in ferry configuration and fuel usage when allocating fuel to freight and passengers, we separated the fleet into four groups: (1) high-speed catamarans, (2) Aleutian chain, (3) southern Southeast day boats (IFA and Lituya), and (4) the remaining mainline ferries. Our consultation with a number of marine architects and review of the literature indicated little agreement on how to allocate fuel used to carry freight and passengers on mixed-use ferries. Based on these discussions and the literature review, we settled on 90% fuel allocated to passengers and 10% fuel allocated to freight on catamarans and day boats, and a 50%-50% split between freight and passengers on main line and Aleutian chain ferries.

Land Transportation

Railroad

Though the Alaska Railroad provided data on tonnage, passengers, and gallons of fuel used by departure and destination for 2006 through 2010, it did not provide fuel cost information. As a result, we substituted Anchorage refinery fuel prices reported by the Oil Price Information Service (OPIS, multiple years) for the missing fuel price information. We also did not receive fuel cost/price information from Alaska trucking companies, so we used the same OPIS prices for a substitute. Thus, while our estimates of fuel prices per gallon are not accurate, they are comparable for rail and truck, which are the two primary competitors for land shipping in the Alaska Railbelt. Our results compare the relative efficiency of freight movement by the two modes, rather than the definitive cost over the period of analysis (GAO, 2011; Center for Neighborhood Technology, 2013).

Trucking

As was true of barge companies, only one long-haul trucking company shared data on tonnage and fuel use by destination. We estimated market share and expanded the data for an all-Alaska tonnage and fuel use evaluation. We used those data to calculate ton-miles of freight moved per gallon of fuel and the cost of fuel per ton-mile for shipping by truck.

Aviation

To estimate fuel used in aviation, we initially attempted to use the U.S. Department of Transportation, Bureau of Transportation Statistics (BTS) data, available for download at www.transtats.bts.gov. Our initial analysis was based on three BTS data sources: T100 segment data, Schedule T2, and schedule P-12(a) (U.S. DOT, RITA, BTS, 2012 a, b, c and d). T100 segment data show the monthly number of flights for a city-pair, also called a flight segment. The T100 data are not based on a sample or survey; they represent a 100% census. All carriers except those with $20 million or less in annual operating revenue submit quarterly balance sheets and fuel reports. Schedule T2 provides quarterly air carrier traffic and capacity statistics by aircraft type and carrier, including the amount of aircraft fuel issued (not used). Schedule P-12(a) shows monthly fuel consumption and fuel cost by carrier, but does not disaggregate fuel consumption and cost by each carrier's aircraft types.

First, we combined ten years of T100 segment data from 2000 to 2010 for flights originating in Alaska, thus including flights within Alaska and the first segment of flights originating in Alaska for out-of-state destinations. The data included both scheduled and unscheduled flights. We then followed the same procedure to combine the same ten years for Schedule T2 and Schedule P-12(a).

In an effort to link the T100, T2, and P-12(a), we tried to estimate fuel used per T100 segment. Therefore, we first used the T2 data to calculate carrier and aircraft-group-specific fuel efficiencies per mile and per hour of flight for each quarter of the year between 2000 and 2010. To do so, we applied the mean quarterly gallons per mile flown or hour flown for each carrier by aircraft type. For cases with missing data on the amount of fuel issued, we applied different approaches, depending on whether we knew the aircraft type and/or aircraft group.

We calculated fuel cost per segment based on Schedule P-12(a). We divided the monthly carrier-specific fuel cost by the monthly carrier-specific fuel amount in gallons, which equals the nationwide monthly average fuel price per carrier. We then applied this carrier-specific monthly fuel price to the fuel consumption per segment to arrive at the fuel cost per segment.

We tested our model results by comparing them with the U.S. Department of Energy (DOE), Energy Information Administration (EIA), State Energy Data System (SEDS) estimate for Alaska aviation fuel use. This comparison indicated that our model estimates using publically available, unlinked data were about an order of magnitude larger. Others have identified similar difficulties using BTS data as well as the non-existence of air freight cost data (Holguín-Veras, José, et al., 2013; Peeters et al., 2005; Siebe, 2012; Lee et al., 2001). Peeters et al. (2005) argues that fuel consumption data from BTS do not take into account the fact that planes load additional reserve fuel, which is issued but not used. Lee et al. (2001) mentioned this as well. Thus, the variable AIRCRAFT_FUELS_921 represents the gallons of fuel issued but not necessarily used. Peeters et al. (2005) write that in order to use the BTS Schedule T-2 data alone, one has to correct for fuel reserves. The authors note that piston-engine aircrafts carry about three hours of reserve fuel, while jets take extra fuel for about 200 nautical miles (230 miles). These factors exacerbate the problems of matching the unlinked fuel used (T-2), segments flown (T100), and fuel cost (P-12[a]) datasets. In Alaska, the problem of discrepancy between the reported fuel issued and fuel used is made worse by the fact that aircraft almost exclusively fuel in the large airports of Anchorage and Fairbanks and very rarely refuel at airports in rural Alaska, where fuel is often more than double the price (Cadavoa, 2010). Also, additional fuel beyond that used in flight and carried for reserve is often transported to rural fuel depots, where it is stored in the airline’s fuel cache for emergencies and other purposes, like heating airline-owned facilities.

Our fallback for estimating fuel use was to use data from the U.S. DOE EIA SEDS. With this data, we estimated total fuel aviation use, but we used BTS data to allocate the fuel to scheduled and unscheduled intra-state flights and flights exiting Alaska by carrier types—passenger, cargo, mixed passenger and cargo, and seaplanes. We used the estimate of fuel used by exiting flights to estimate fuel used by scheduled and unscheduled flights entering Alaska. The variables and data used from specific data sources are shown in Appendix C.

While this method provides a more reasonable estimate of fuel used by different carrier configurations, the level of aggregation is too great to estimate fuel use per ton-mile or per passenger-mile, which does not facilitate a comparison of energy efficiency or costs across transportation modes. To find potential proxies, we consulted the literature.

Economic Impact Analysis of Fuel Price Changes on the Alaska Economy

The foundation of modern input-output analysis is based on work started in the 1930s by Wassily Leontief (Leontief, 1936, 1966). Economic theory abstractly describes the relationships between prices and quantities with respect to supply and demand in a market economy. The ways that these relationships unfold in reality, however, are based on innumerable individual transactions involving a vast array of inputs, products, and services. By collecting, aggregating, and tabulating detailed industrial output data into a matrix, in which the output of every industry may serve as the input to a variety of other industries in an economy, Leontief created an analytic tool that bridges the gap between the abstraction of economic theory and the empirical detail found in economic data.

Table 2 provides an illustration of this input-output transactions tool. The columns represent the variety of industrial input requirements (demand), and the rows represent the distribution of industrial output (supply). In addition to the square industry-by-industry transaction matrix (producing sectors), the model includes a vector at the bottom for value added and a vector along the right-hand side of the matrix for final demand. The value-added vector comprises primary factor inputs to production, such as capital and labor services. The final demand vector comprises the components that make up gross domestic product (GDP): consumption, investment, imports, exports, and government. Because of the basic accounting premise that all outputs in an economy must equal all inputs, the total output for a given industry can be calculated as either the column sum of intermediate inputs and value added, or as the row sum of intermediate and final demand for its output. In addition, total value added (the row sum of the vector), which represents all the income in the economy, must equal total final demand (the column sum of the vector), which represents the output of the economy.

Table 2. Illustrative input-output transactions table (in millions of dollars)

	Producing Sector			Consuming Sector			
	Industry A	Industry B	Industry C	Exports	Households	Total Final Demand	Total Sales (A+B+C+TFD)
Producing Sectors							
Industry A	**10**	**5**	**3**	**1**	**12**	**13**	**31**
Industry B	**3**	**9**	**8**	**1**	**4**	**5**	**25**
Industry C	**8**	**4**	**6**	**3**	**3**	**6**	**24**
Primary Inputs							
Value Added	**10**	**7**	**7**	**0**	**8**	**8**	**32**
Total Inputs	**31**	**25**	**24**	**5**	**27**	**32**	**112**

The values in the matrix and the vector represent dollar transaction values, each comprising a price component and a quantity component. The nominal transaction values in the matrix and the vector can be converted into coefficients by dividing each column value by the value of total industry output. The calculated coefficients represent the proportions of inputs required to produce a single unit of output, and each column sums to one. This matrix of coefficient values, known as the matrix or the direct requirements matrix, can be thought of as the production "recipes" for each industry. When viewed as a whole, the entire matrix provides a snapshot of the current technological state of an economy. For more details on input-output modeling and terminology, see Appendix D.

IMPLAN

IMPLAN (IMpact analysis for PLANning) is a system for conducting economic analyses based on national input-output (I/O) structural matrices (MIG, Inc., 2011). IMPLAN was originally developed by the U.S.

Forest Service and has gained wide acceptance in a variety of impact assessment applications. In addition to the U.S. Forest Service, users of IMPLAN have included the U.S. Army Corps of Engineers, the National Park Service, the Soil Conservation Service, the Federal Emergency Management Agency, the Bureau of Land Management, universities, and numerous state and regional planning agencies.

The basic IMPLAN model performs an I/O analysis for a given region in terms of as many as 509 economic sectors (257 for Alaska), roughly corresponding to NAIC (North American Industry Classification) codes. In addition, IMPLAN allows the analyst to add custom sectors for a particular application. Impacts are specified in terms of output, income, and employment.

The economic impacts estimated by input-output models reflect the direct expenditures of a particular sector (study sector) and account for the "ripple effect" of economic activity resulting from that sector. Employees of the study sector and local businesses from which the study sector purchased goods and services continue to spend at least some percentage of these monies locally, spurring additional economic impacts. The initial expenditure essentially spurs a chain of indirect and induced spending. Input-output models use a series of "multipliers" to estimate the economic impacts associated with each initial dollar of direct spending. We use IMPLAN to analyze how the fuel price changes that occurred from 2009 to 2010 (approximately 28%) affected the Alaska economy as depicted in 2008 before the price increases. To the extent possible, we analyzed transportation fuel prices from 2006 to 2010, because that period witnessed dramatic changes in prices (Figure 9).

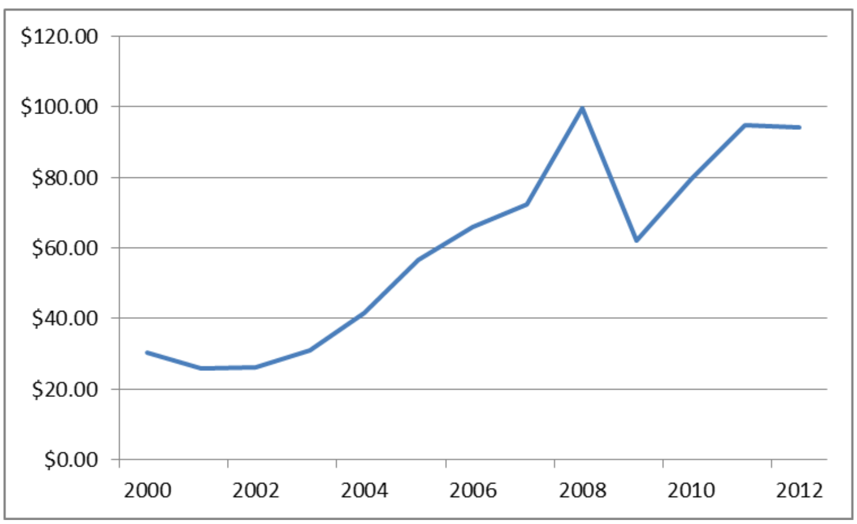


Figure 9. Annual crude oil prices, 2000–2012

Source: U.S. Energy Information Administration, Cushing, OK WTI Spot Price FOB (Dollars per Barrel).

Findings and Applications

Fuel Use and Efficiency by Mode

Water Transportation

Marine ships and barges carry an estimated 146–186 ton-miles per gallon of fuel (a ton-mile is the movement of one ton of freight one mile); they are well laden despite the fact that they primarily carry freight into Alaska and return considerably less laden. Despite already reflecting relatively higher fuel efficiency per ton-mile, the data indicate increasing efforts to move freight even more efficiently as fuel prices increased in 2008 (Winebrake, James J. and James J. Corbett, 2010) . However, because of the confidentiality of proprietary data, specific details cannot be presented. Table 3 and Table 4 show our estimates of average fuel use, costs, and fuel use per ton-mile of freight shipped for marine ships and barges.

Table 5 shows regional barge fuel use estimates from our barge fuel-use model.

Marine Ships

Table 3. Estimated fuel usage and costs for freight movement by marine vessels 2006–2010, 2011$

Average ship miles per gallon	0.02
Average ship ton-miles per gallon	146
Average fuel costs per mile	$102
Average fuel costs per ton-mile	$0.012

Source: OPIS Anacortes fuel prices, author calculations.

Barges

Table 4. Estimated tons, fuel usage and costs for freight movement by barge 2006–2012, 2011$

Average barge miles per gallon	0.04
Average barge ton-miles per gallon	186
Average fuel costs per mile	$51
Average fuel costs per ton-mile	$0.016

Source: Marine fuel prices, U.S. Waterborne statistics, author calculations.

Table 5. Estimated regional fuel usage for freight movement by barge 2006–2012, 2011$

Southcentral	2006	2007	2008	2009	2010
Fuel (gallons)	15,469,855	15,405,158	15,265,487	15,154,696	13,438,447
Fuel costs	$45,288,048	$45,420,378	$61,122,310	$38,201,410	$39,984,049
Distance	843,271	839,744	832,131	826,092	732,538
Miles/gallon	0.05	0.05	0.05	0.05	0.05
Fuel costs/mile	$54	$54	$73	$46	$55
Southeast					
Fuel (gallons)	9,269,933	9,570,533	8,568,850	9,844,300	9,194,950
Fuel costs	$27,022,116	$28,254,127	$33,854,190	$24,918,379	$27,427,971
Distance	640,059	660,814	591,651	679,717	634,882
Miles/gallon	0.07	0.07	0.07	0.07	0.07
Fuel costs/mile	$42	$43	$57	$37	$43
Western					
Cargo	2,272,073	2,386,748	1,977,094	2,037,358	2,106,688
Fuel (gallons)	9,311,500	9,294,750	9,623,375	9,226,000	8,878,000
Fuel costs	$27,535,811	$26,928,952	$39,333,492	$22,615,153	$26,373,031
Distance	428,619	427,848	442,975	424,684	408,665
Miles/gallon	0.05	0.05	0.05	0.05	0.05
Fuel costs/mile	$64	$63	$89	$53	$65
Inland*					
Fuel (gallons)	119,880	119,880	119,880	119,880	119,880
Fuel costs	$346,837	$361,320	$477,498	$313,125	$369,396
Distance	13,796	13,796	13,796	13,796	13,796
Miles/gallon	0.12	0.12	0.12	0.12	0.12
Fuel costs/mile	$25	$26	$35	$23	$27
Total					
Gallons	34,171,168	34,390,321	33,577,592	34,344,876	31,631,277
Cost (2011$)	$100,192,812	$100,964,777	$134,787,490	$86,048,067	$94,154,448

* Inland waterways figures are minimum estimates based on 2010 U.S. Census population.

Sources: U.S. Waterborne Statistics, multiple years; Fisheries Economics Data Program, Monthly Marine Fuel Prices, http://www.psmfc.org/efin/data/fuel.html, author calculations.

Ferries

Ferries serve as part of the Alaska highway system in locations where no roads exist—primarily Southeast Alaska, Prince William Sound, and the Aleutian chain. They also connect Southeast and Southcentral Alaska to the Lower 48 highway system, with voyages to and from Bellingham, Washington, and Prince Rupert, British Columbia. Ferries are constructed to handle rough seas and have traditionally carried passenger vehicles and freight—and both those factors reduce their fuel-use efficiency. However, ferries have always been under pressure not to compete with the private sector for freight, so their tariffs are set to be non-competitive, and as a result, they primarily carry freight cargo to smaller communities where barge service is not economical. So it can be expected that the fuel and operating efficiencies are lower for AMHS ferries than for private shipping and barge companies (Table 6 and

Table 7). Given the age and configurations of Alaska ferries, the policy of avoiding direct competition with the private sector, and the schedules operated to meet the needs of the traveling public, it is unlikely that ferries could ever be as fuel-efficient as their private-sector counterparts. The AMHS ferries operate on less than a tenth of the ton-miles per gallon as barges and ships, primarily because they use less of their capacity. Keep in mind that ferries provide essential transportation services to locations not connected to roads.

For the years analyzed, passenger-miles per gallon for ferries ranged from 11 to 13 (Table 6 and Table 8), making ferries the least fuel efficient for moving passengers of all the modes analyzed, including air. This lack of fuel efficiency results from low capacity factors and high fuel use. Compared with national figures, Alaska ferries on average have lower fuel efficiencies than passenger vehicles have (Ghanta, 2010). Day boat and catamaran service appear to improve these statistics, because more space is dedicated to passengers and the service schedule is more closely tied to travelers' schedules. Table 9 provides more details on fuel use by the four groups of ferry service, as discussed in the methods section: (1) high-speed catamarans, (2) Aleutian chain, (3) southern Southeast day boats (IFA and Lituya), and (4) the remaining mainline ferries. Considerably more analysis is available for the ferry system because of the data received, and can be provided upon request.

Table 6. Passengers, freight, fuel usage, and costs for the Alaska Marine Highway System and Inter-Island Ferry Authority 2007–2010, 2011$

	2007	2008	2009	2010
Total passengers	589,599	603,890	563,302	579,508
Total cargo deck freight (short tons)	688,646	666,529	658,575	664,407
Fuel use, passenger share	7,089,193	6,320,160	5,912,334	6,153,616
Fuel use, freight share	4,857,297	4,135,185	4,237,976	4,296,995
Total fuel use (gallons)	11,946,490	10,455,345	10,150,310	10,450,611
Total fuel cost (2011$)	$30,493,483	$38,107,148	$22,896,161	$28,345,120
Total miles	726,196	666,298	640,738	645,955
Miles/gallon	0.06	0.06	0.06	0.06
Fuel cost per mile	$42	$57	$36	$44
Ton miles/gallon	18	18	20	20
Fuel cost per ton-mile	$2.28	$3.28	$1.74	$2.18
Ton miles (freight)	88,844,314	78,258,524	77,939,792	80,028,674
Passenger miles	68,401,657	65,009,076	61,092,295	64,055,703
Passenger miles/ gallon	11	11	12	13
Fuel cost per passenger-mile	$3.81	$5.25	$2.81	$3.45
Passenger % utilization (AMHS)	24%	27%	28%	28%

Sources: ADOT&PF, AMHS; IFA; U.S. DOE, EIA; author calculations.

Table 7. Estimated tons, fuel usage, and costs for freight movement for the Alaska Marine Highway System and Inter-Island Ferry Authority 2007–2010, 2011$

Average miles per gallon	0.06
Average ton-miles per gallon	19
Average fuel costs per mile of ship operation	$45
Average fuel costs per ton-mile	$2.37

Sources: ADOT&PF, AMHS; IFA; U.S. DOE, EIA; author calculations.

Table 8. Estimated tons, fuel usage, and costs for passenger movement by the Alaska Marine Highway System and Inter-Island Ferry Authority, 2007–2010, 2011$

Average miles per gallon	0.06
Average passengers-miles per gallon	12
Average fuel costs per mile of ship operation	$45
Average fuel costs per passengers-mile	$3.83

Sources: ADOT&PF, AMHS; IFA; U.S. DOE, EIA; author calculations.

Table 9. Annual passengers and freight by segment type for the Alaska Marine Highway System and Inter-Island Ferry Authority segment types 2007–2010, 2011$

Ferry "type"	2007	2008	2009	2010
Total Passengers (Count)				
Aleutian	35,096	33,129	34,182	35,581
Catamaran	88,880	74,997	55,490	62,299
IIF	88,620	85,665	81,878	79,800
Main Line	377,003	410,099	391,752	401,828
Total	589,599	603,890	563,302	579,508
Total Freight (Short Tons)				
Aleutian	43,400	42,843	48,014	45,802
Catamaran	84,287	70,791	55,403	62,095
IIF	81,332	68,838	66,498	65,185
Main Line	479,627	484,057	488,660	491,325
Total	688,646	666,529	658,575	664,407
Gallons per Segment				
Aleutian	1,414,387	988,542	1,146,682	1,154,950
Catamaran	2,283,737	2,324,169	1,697,233	1,989,729
IIF	506,132	407,050	395,715	331,048
Main Line	7,742,234	6,735,584	6,910,680	6,974,884
Total	11,946,490	10,455,345	10,150,310	10,450,611
Fuel Cost (2011$)				
Aleutian	$3,625,386	$3,635,715	$2,842,751	$3,377,013
Catamaran	$5,955,128	$9,338,305	$3,831,519	$5,500,718
IIF	$1,352,102	$1,379,505	$798,404	$862,022
Main Line	$19,560,866	$23,753,623	$15,423,486	$18,605,367
Total	$30,493,483	$38,107,148	$22,896,161	$28,345,120
Statute Miles per Segment				
Aleutian	93,534	69,679	75,069	76,152
Catamaran	112,865	117,281	85,799	93,996
IIF	58,078	49,800	49,806	45,761
Main Line	461,719	429,538	430,064	430,046
Total	726,196	666,298	640,738	645,955

Sources: ADOT&PF, AMHS; IFA; U.S. DOE, EIA; author calculations.

Land Transportation

Railroad

The Alaska Railroad provides freight and passenger service along the corridor from Fairbanks to Seward and Whittier. Approximately a third of the tonnage of the railroad's freight service was refined petroleum products in 2007. However, with production declines at the Flint Hills refinery, petroleum products' share of total freight has declined. The railroad showed ton-mile per gallon freight efficiencies from 256 to 311 tons per mile during the study period (Table 10, Table 12, and Figure 10). The national rail service company, CSX, advertises almost 500 ton-miles per gallon, but Lower 48 trains and segment distances are considerably longer (CSX, 2012). Also, it is not clear whether CSX calculations include only full loads and exclude empty back hauls; empty back hauls reduce the ton-miles per gallon for the Alaska Railroad.

Table 10. Fuel usage and costs for freight movement by the Alaska Railroad 2007–2010, 2011$

		Fuel		Ton-mile/	Fuel cost/
Year	**Short tons**	**Gallons**	**Cost**	**gallon**	**ton-mile**
2007	6,592,506	4,342,932	$11,135,924	260	$0.010
2008	6,897,737	3,241,907	$11,083,097	288	$0.012
2009	6,626,029	3,618,137	$8,341,123	311	$0.007
2010	7,069,781	3,993,404	$11,042,024	256	$0.011
Average	6,796,513	3,799,095	$10,400,542	279	$0.010

Source: Alaska Railroad data, OPIS Anchorage fuel prices, author calculations.

Table 11. Alaska Railroad freight transport in short tons, petroleum and all other goods

	Short tons		
	Petroleum	**AOG**	**Total**
2007	2,202,162	4,390,344	6,592,506
2008	1,911,157	4,986,580	6,897,737
2009	1,657,763	5,179,170	6,836,933
2010	1,253,894	5,815,887	7,069,781

Source: Alaska Railroad data, multiple years.

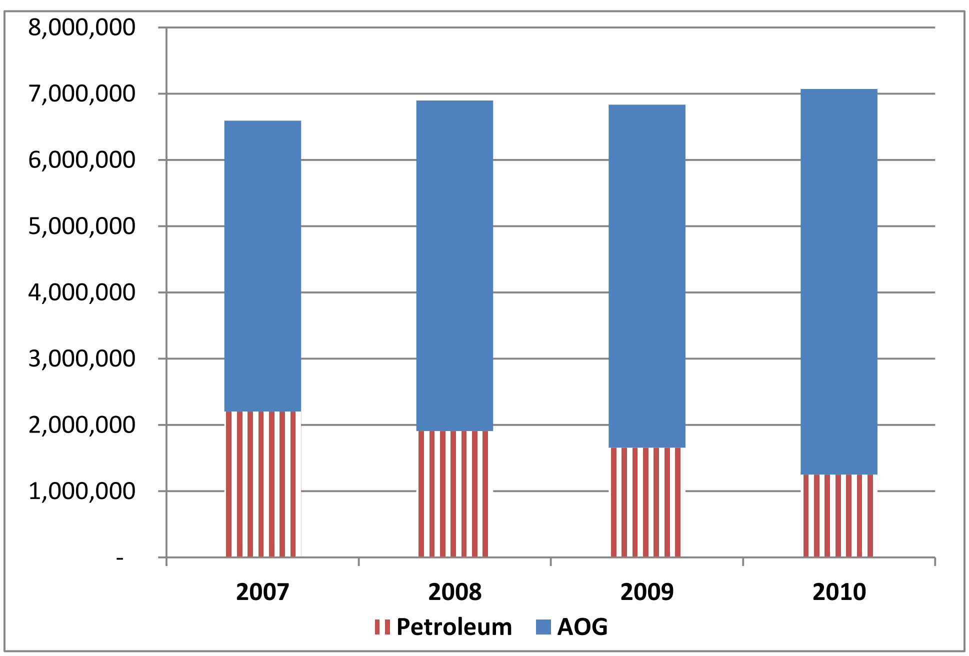


Figure 10. Alaska Railroad freight transport in short tons, petroleum and all other goods (AOG), 2007–2009
Source: Alaska Railroad data

The estimates of fuel costs per mile and fuel costs per ton-mile (Table 12) are based on OPIS Anchorage refinery prices, because the Alaska Railroad provided no fuel price information. Most likely the OPIS prices are lower than the railroad's actual fuel costs, but because it transports refined fuels for refineries and uses large quantities, the railroad may negotiate prices that are relatively close to OPIS wholesale prices. Also, in the absence of actual data, the OPIS prices are the most appropriate substitute. But the fuel costs provided in Table 12 might not be accurate, and should not be compared with other modes, like ferries, that provided actual price information.

Table 12. Average fuel usage and costs for freight movement by the Alaska Railroad 2007–2010, 2011$

Average miles per gallon	0.13
Average rail ton-miles per gallon	279
Average fuel costs per mile	$21
Average fuel costs per ton-mile	$0.01

Source: Alaska Railroad data, OPIS Anchorage fuel prices, author calculations.

The Alaska Railroad averages approximately 100 to 150 passenger-miles per gallon of fuel (Table 13 and Table 14). The low end of the range is approximately 40% higher than Amtrak's national average, and the upper end is almost double (Ghanta, 2010). The pull contracts for the cruise ship companies taking visitors to Denali National Park and Preserve provide good utilization rates, as these are relatively long, well-used passenger trains.

Table 13. Fuel usage and costs for passenger movement by the Alaska Railroad 2007–2010, 2011$

		Fuel		Passenger-mile/	Fuel cost/
Year	**Passengers**	**Gallons**	**Cost**	**gallon**	**Passenger-mile**
2007	670,868	1,220,758	$3,092,549	102	$0.02
2008	675,626	1,228,142	$4,879,996	123	$0.03
2009	586,149	1,195,411	$2,811,418	148	$0.01
2010	516,480	1,149,241	$3,158,125	107	$0.03
Average	612,281	1,198,388	$3,485,522	120	$0.02

Source: Alaska Railroad data, OPIS Anchorage fuel prices, author calculations.

Table 14. Average fuel usage and costs for passenger movement by the Alaska Railroad 2007–2010, 2011$

Average miles per gallon	0.2
Average rail passengers-miles per gallon	120
Average fuel costs per mile	$15
Average fuel costs per passengers-mile	$0.02

Source: Alaska Railroad data, OPIS Anchorage fuel prices, author calculations.

Trucks

Our truck fuel-use estimates are based on limited information and should be used with caution. The fuel use per mile reported in Table 15 is higher than the national average of 6 miles per gallon and the average of 59 ton-miles per gallon (U.S. Department of Transportation, 2010). These higher Alaska fuel use rates most likely can be attributed to Alaska's colder conditions and mountainous terrain, and to road systems that are not comparable to Lower 48 interstate highways.

Table 15. Estimated fuel usage and costs by long-haul trucks, 2011$

Average truck miles per gallon	4.5
Average truck ton-miles per gallon	48
Average fuel costs per mile	$0.61
Average fuel costs per ton-mile	$0.06

Source: OPIS Anchorage fuel prices, author calculations.

As was true for the Alaska Railroad, we did not receive any fuel cost information for trucks, so we substituted OPIS Anchorage refinery prices for truck diesel prices. Despite the fact that some companies haul fuel for refineries, the numerous trucking companies most likely purchase fuel in smaller quantities than the railroad does, so this fuel price estimate is more likely to be low for trucks than for the railroad. As a result, truck fuel costs should not be compared with those of other modes and compared cautiously with those of the railroad.

Aviation

Table 16 provides information on estimated fuel used for scheduled and unscheduled intra-state flights, scheduled and non-scheduled flights exiting Alaska, and scheduled and unscheduled flights entering Alaska for the years 2005 through 2010 (additional details are available in Appendix D). The information includes the total reported fuel consumed, total fuel costs, estimated price of fuel per gallon, number of passengers, tons of freight and mail, and fuel used for the four primary carrier types providing service to Alaska markets and freight carriers traveling through Alaska.

The total fuel used by the aviation sector ranged from a low of approximately 1.6 billion gallons in 2009 during the recession to 2.4 billion gallons in 2007 prior to the recession and the dramatic increase in crude oil prices. Of this total, in 2010, scheduled intra-state flights used approximately 1.5%, non-scheduled intra-state flights used 0.4%, flights exiting Alaska used an estimated 48.8%, and flights entering Alaska used 49.3%. Cargo flights entering and exiting Alaska used about 10 times the amount of fuel as passenger flights entering and exiting Alaska.

As discussed in the methods section, the distance information is the summation of segments traveled, but does not account for the number of times each segment was traveled. As a result, it is not possible to calculate passenger-miles or ton-miles per gallon of fuel or fuel costs per mile, passenger-mile, or ton-mile for aviation.

Airlines spend 10% or more of their operating budgets on fuel purchases, making fuel the air industry's second largest expense category, after labor cost (Wells, 2011; Ghanta, 2010). A literature review on fuel consumption by air carriers shows increasing fuel conservation efforts among air carriers. In the 20-year period from 1970 to 1990, fuel efficiency nearly doubled, increasing from 26.2 seat-miles per gallon (SMPG) in 1970 to 49 SMPG in 1989. In the 1990s, fuel efficiency reached 65–80 SMPG. Approaches to minimize fuel consumption include continuous descents from altitude, increased monitoring of fuel use, and improved effectiveness of aircraft loading (Peeters et al., 2005; Stolzer, 2002; Wells, 2011; Ghanta, 2010; Lee et al., 2001). Based on this review, we used 50 passenger-miles per gallon of fuel for comparison with other modes.

Table 16. Fuel usage and costs for intra-state scheduled air transportation in Alaska 2005–2010, 2011$

	2007	2008	2009	2010
Intra-state scheduled				
Total gallons	30,684,229	31,457,698	27,330,122	27,846,200
Totalcost [2011$]	$79,832,197	$103,765,976	$55,388,981	$69,842,835
Average price [$/gal]	$2.60	$3.30	$2.03	$2.51
Passengers	3,165,770	3,175,766	2,801,996	2,958,337
Freight	99,460	97,430	90,176	94,379
Mail	114,531	114,771	106,317	106,877
CO_2 emissions [mt]	293,587	300,987	261,495	266,432
Intra-state unscheduled				
Total gallons	5,963,125	9,301,368	6,732,250	7,859,375
Totalcost [2011$]	17,190,711	32,761,806	16,001,674	17,258,454
Average price [$/gal]	$2.88	$3.52	$2.38	$2.20
Passengers	195,941	185,469	197,444	170,207
Freight	19,601	21,541	35,116	19,025
Mail	565	373	151	112
CO_2 emissions [mt]	57,055	88,995	64,414	75,199
Exiting (Scheduled & unscheduled)				
Total gallons	1,193,994,646	967,954,934	762,383,628	925,632,425
Totalcost [2011$]	2,856,751,124	3,063,036,030	1,427,105,264	2,169,344,617
Average price [$/gal]	$2.39	$3.16	$1.87	$2.34
Passengers	2,215,930	2,062,806	1,844,701	1,893,169
Freight	3,005,120	2,456,141	1,988,147	2,472,836
Mail	4,778	4,196	2,664	4,009
CO_2 emissions [mt]	11,411,037	9,250,826	7,283,021	8,847,839
Entering (Scheduled & unscheduled)				
Total gallons	1,207,421,777	982,127,718	772,386,783	934,194,928
Totalcost [2011$]	$2,888,876,874	$3,107,884,964	$1,445,830,162	$2,189,412,000
Average price [$/gal]	$2.39	$3.16	$1.87	$2.34
Passengers	2,215,930	2,062,806	1,844,701	1,893,169
Freight	3,005,120	2,456,141	1,988,147	2,472,836
Mail	4,778	4,196	2,664	4,009
CO_2 emissions [mt]	11,539,361	9,386,276	7,378,581	8,929,685

Notes: Numbers in black are directly from the BTS and EIA data. Blue numbers were calculated from BTS and EIA data.
Sources: U.S. DOT, BTS; U.S. DOE, EIA; FAA; author calculations.

Intermodal Fuel Use Comparisons

As previously stated, the variability of available data makes direct comparisons of energy use difficult, but we can use our information to gain a broad understanding of the relative differences in fuel use across the modes to help illustrate differences in vulnerabilities to fuel price changes and potential emissions taxes. Despite the limitation of the data, Figure 11,Figure 12, and Figure 13 and Table 17 provide "overview" comparisons of fuel used and the estimated costs of fuel for the four travel modes analyzed from 2007 to 2010.

Table 18 through Table 20 and Figure 14 and Figure 15 compare estimated direct fuel use and costs across the four modes analyzed. Again, because of lack of precision, comparisons should be used in the context of general "ranges of magnitude." This is especially true for rail and trucking, where we received no fuel price information. In the absence of this information, we substituted OPIS Anchorage refinery diesel prices (as discussed earlier). So these comparisons are imprecise for rail and trucking to the extent to which the two pay different mark-ups from wholesale refinery prices.

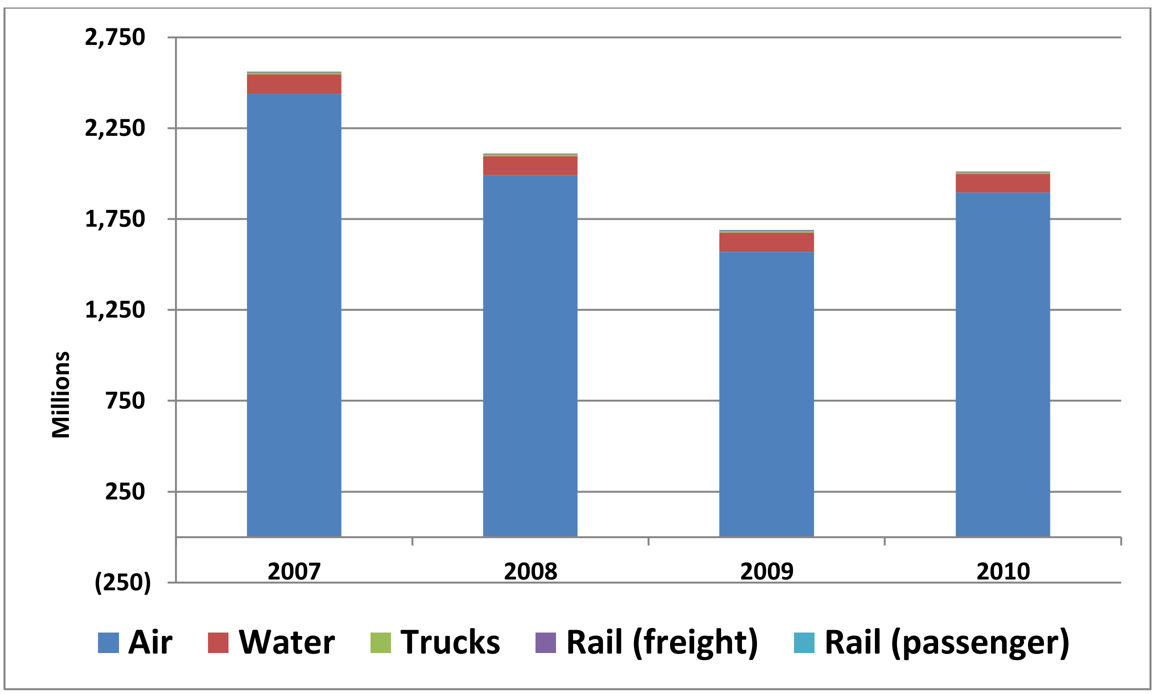


Figure 11. Comparison of annual fuel use, 2007–2010

Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Waterborne Statistics; AMHS; AKRR; IFA; company proprietary information; author calculations. The 2010 truck data are used in all four years in place of missing data.

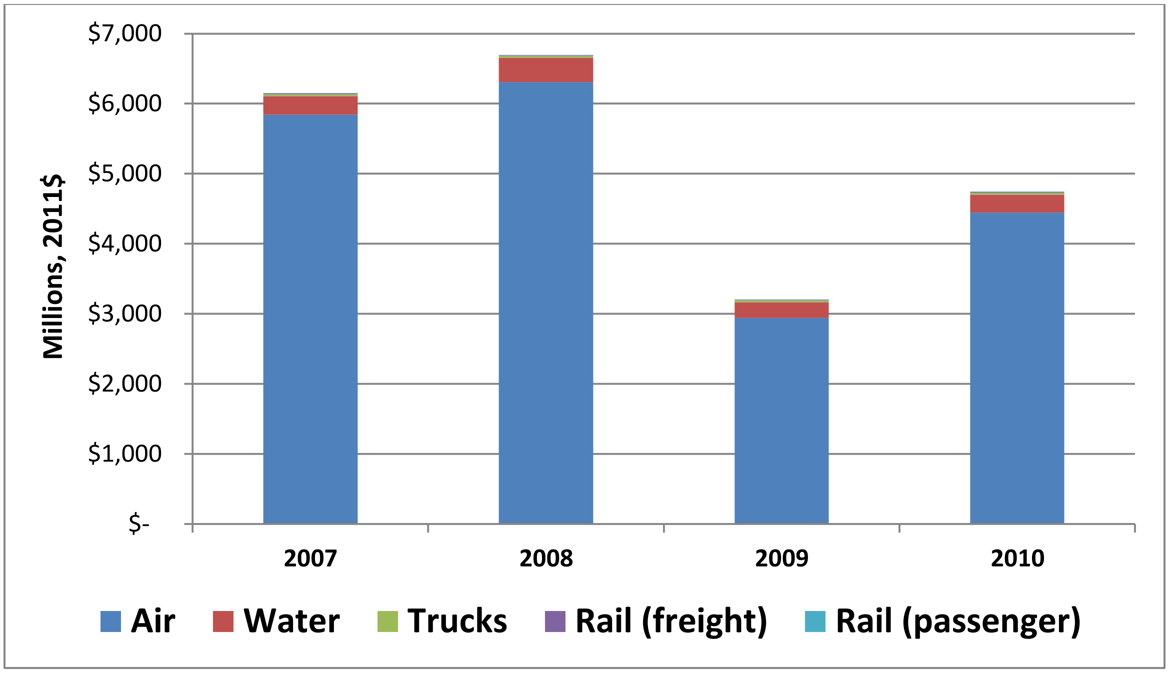


Figure 12. Comparison of annual fuel costs, 2007–2010, 2011$
Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Waterborne Statistics; AMHS; AKRR; IFA; company proprietary information; author calculations. The 2010 truck data are used in all four years in place of missing data.

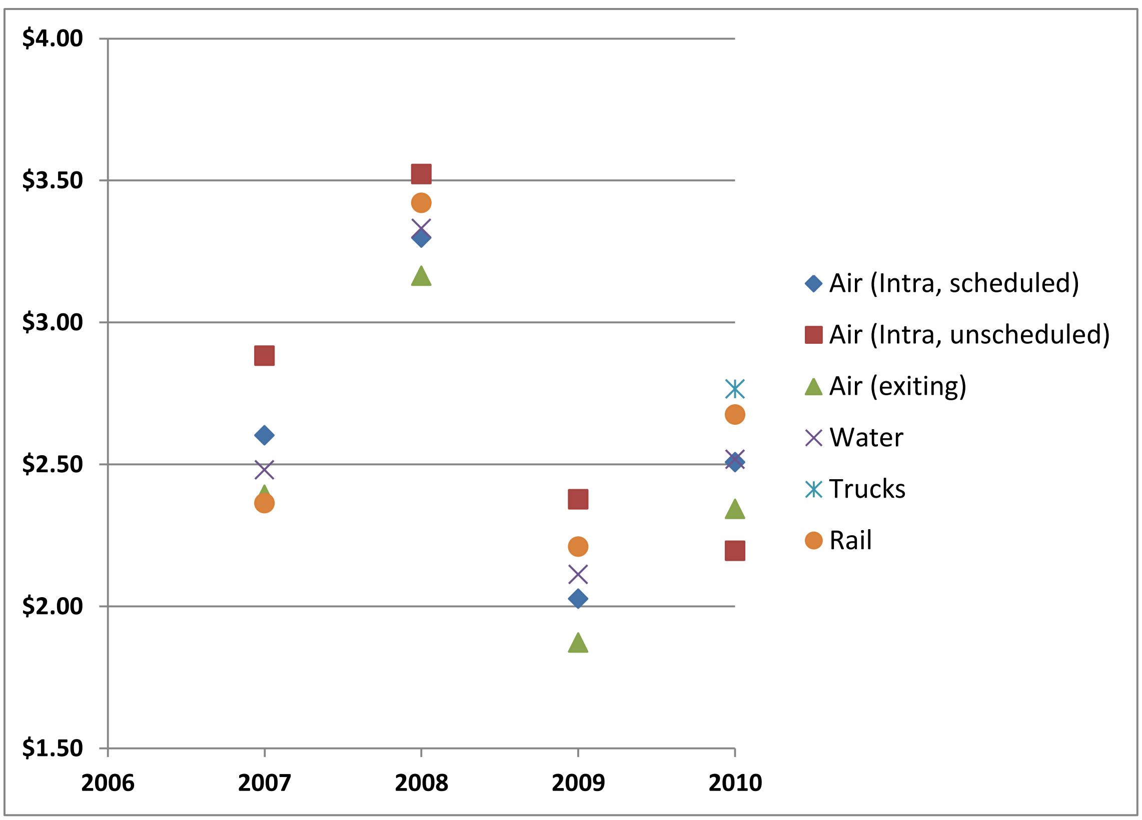


Figure 13. Comparison of annual fuel prices per gallon, 2007–2010, 2011$
Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Waterborne Statistics; AMHS; AKRR; IFA; company proprietary information; author calculations. The 2010 truck data are used in all four years in place of missing data.

Table 17. Estimated transportation fuel use and costs, Alaska 2007–2010

		2007	2008	2009	2010
Aviation					
Scheduled intra-state		**2007**	**2008**	**2009**	**2010**
gallons		30,684,229	31,457,698	27,330,122	27,846,200
cost (2011$)		$79,832,197	$103,765,976	$55,388,981	$69,842,835
Reported average price [$/gal]		$2.60	$3.30	$2.03	$2.51
Non-scheduled intra-state					
gallons		5,963,125	9,301,368	6,732,250	7,859,375
cost (2011$)		$17,190,711	$32,761,806	$16,001,674	$17,258,454
Reported average price [$/gal]		$2.88	$3.52	$2.38	$2.20
Exiting (scheduled & non-scheduled)					
gallons		1,193,994,646	967,954,934	762,383,628	925,632,425
cost (2011$)		$2,856,751,124	$3,063,036,030	$1,427,105,264	$2,169,344,617
Reported average price [$/gal]		$2.39	$3.16	$1.87	$2.34
Entering (scheduled & non-scheduled)					
		1,207,421,777	982,127,718	772,386,783	934,194,928
		$2,888,876,874	$3,107,884,964	$1,445,830,162	$2,189,412,000
		$2.39	$3.16	$1.87	$2.34
Aviation total	**gallons**	2,438,063,777	1,990,841,718	1,568,832,783	1,895,532,928
	cost (2011$)	$ 5,842,650,906	$ 6,307,448,776	$ 2,944,326,080	$ 4,445,857,906
Estimared average price [$/gal]		$2.40	$3.17	$1.88	$2.35
Water					
Barges/Ships	**gallons**	95,383,724	94,056,619	95,190,267	91,307,812
	cost (2011$)	$235,744,675	$309,973,422	$199,572,877	$227,870,320
	gal. (intra-state & exiting)	78,243,753	77,260,621	78,012,015	73,839,840
Ferries	**gal. (intra-state & exiting)**	11,946,490	10,455,345	10,150,310	10,450,611
	cost (2011$)	$30,493,483	$38,107,148	$22,896,161	$28,345,120
Total Water	**gallons**	107,330,214	104,511,963	105,340,577	101,758,423
	cost (2011$)	$266,238,157	$348,080,571	$222,469,038	$256,215,440
Estimared average price [$/gal]		$2.48	$3.33	$2.11	$2.52
Trucks (only one year of data)					
	gallons				9,786,844
	cost (2011$)				$27,068,061
	gal. (intra-state & exiting)				8,805,455
Estimared average price [$/gal]					$2.77
Railroad					
	gallons (freight)	4,342,932	3,241,907	3,618,137	3,993,404
	cost (2011$)	$10,291,981	$10,615,993	$7,959,087	$10,699,636
	gallons (passengers)	1,220,758	1,228,142	1,195,411	1,149,241
Total rail	**cost (2011$)**	$2,858,178	$4,674,326	$2,682,651	$3,060,199
	gallons	5,563,690	4,470,049	4,813,548	5,142,645
	cost (2011$)	$13,150,160	$15,290,319	$10,641,738	$13,759,835
Estimared average price [$/gal]		$2.36	$3.42	$2.21	$2.68

Notes: Numbers in black are directly from the BTS and EIA data. Blue numbers were calculated from BTS and EIA data. Total weight includes freight, mail, and passengers. Aircraft type numbers are T100 data codes. Fuel prices in blue are estimates based on OPIS price data and limited proprietary data provided.

Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Waterborne Statistics; AMHS; AKRR; IFA; company proprietary information; author calculations.

Table 18. Comparison of fuel use and costs per ton-mile for Alaska water transportation, 2007–2010, 2011$

	Water		
	Barges	Ships	Ferries
Average ton-miles per gallon of fuel	186	146	19
Average fuel costs per ton-mile	$0.016	$0.021	$2.37
CO2 emissions per ton mile (kilograms)	0.05	0.08	0.53

Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Waterborne Statistics; AMHS; AKRR; IFA; company proprietary information; author calculations.

Table 19. Comparison of fuel use and costs per ton-mile for rail and trucking, 2007–2010, 2011$

	Railroad	Trucks
Average miles per gallon	0.1	4.5
Average ton-miles per gallon of fuel	280	48
Average fuel costs per mile	$21	$0.61
Average fuel costs per ton-mile	$0.03	$0.27

Sources: U.S. DOT, BTS; U.S. DOE, EIA; AKRR; company proprietary information; author calculations.

Table 20. Comparison of fuel use and costs per passenger-mile for rail, ferry and air, 2007–2010, 2011$

	Railroad	Ferry	Air*
Average miles per gallon	0.2	0.06	--
Average passengers-miles per gallon of fuel	120	12	50
Average fuel costs per mile	$15	$45	--
Average fuel costs per passengers-mile	$0.02	$3.83	$0.09

*U.S. average for comparison purposes only.

Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Army Corps of Engineers, Waterborne Statistics; AMHS; AKRR; IFA; Ingram, 2008; company proprietary information; author calculations.

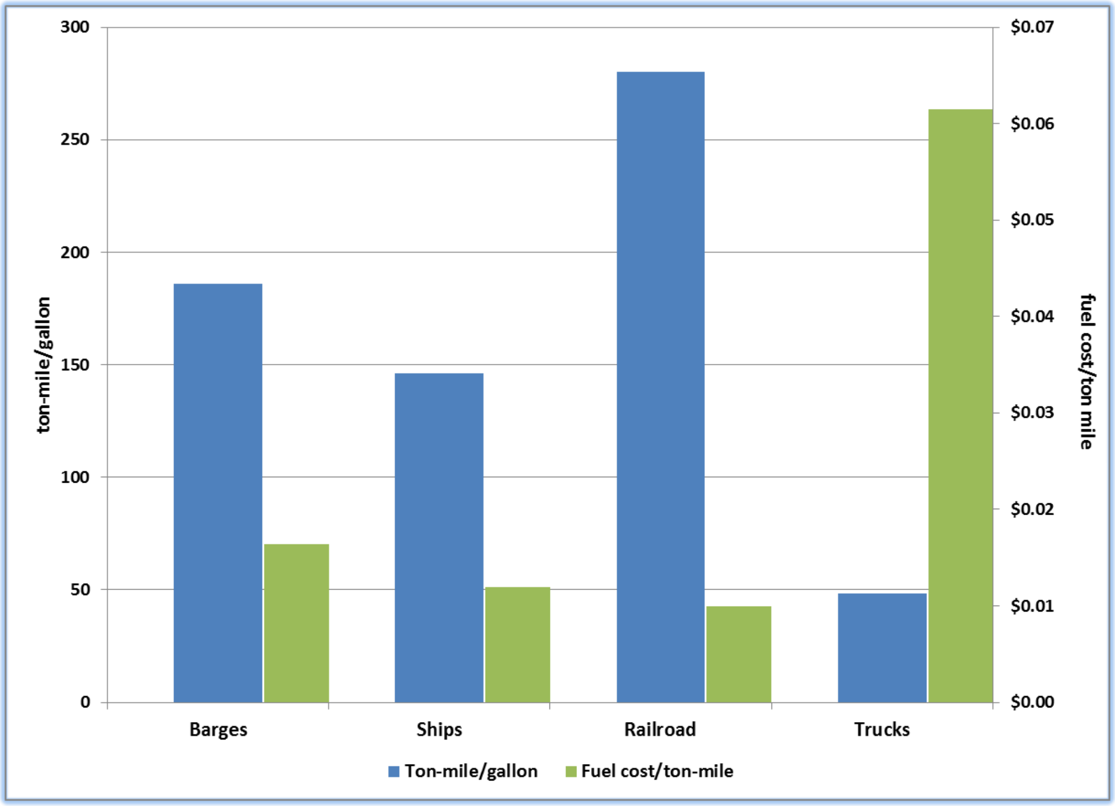
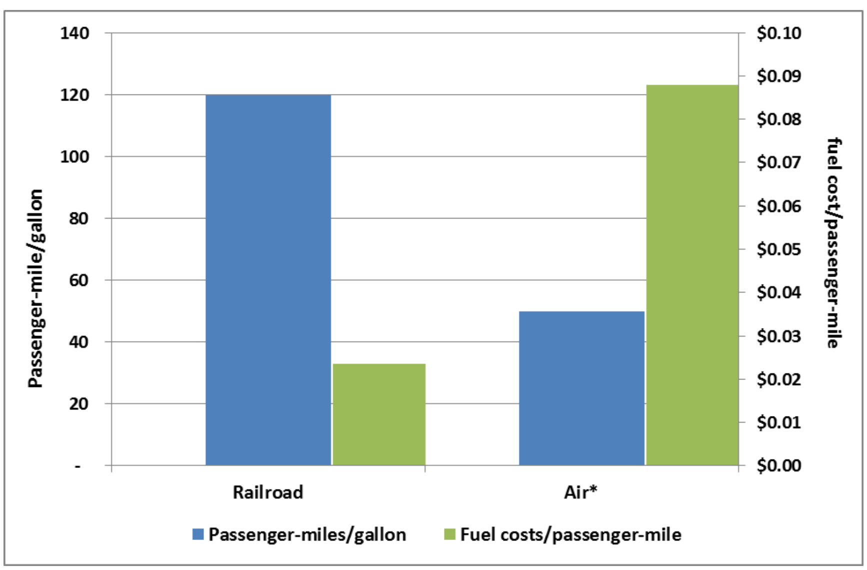


Figure 14. Comparison of fuel use and costs per ton-mile for Alaska transportation, 2007–2010, 2011$
Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Waterborne Statistics; AMHS; AKRR; IFA; company proprietary information; author calculations.



*U.S. average for comparison purposes only.

Figure 15. Comparison of fuel use and costs per passenger-mile for rail and air, 2007–2010, 2011$
Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Army Corps of Engineers, Waterborne Statistics; AMHS; AKRR; IFA; Ingram, 2008; company proprietary information; author calculations.

Change in Transportation Costs and Impact on Alaska Industries

This section examines the economic impact of changes in oil prices and refined petroleum fuel prices on the Alaska economy, industries, and households, and the resulting effect of those changes on transportation services. We initiate the discussion with a description of the Alaska transportation sectors analyzed—air, water, truck, and rail—in employment, payroll, and the number of firms in 2008 (Table 21) and compare these characteristics and changes with data from 2010 (Table 22 and Table 23).

Rail transportation does not appear in these employment numbers because Alaska Railroad employees are state employees; those numbers are part of the state government sector.

Table 21. Alaska transportation sector employment, payroll, and firms by transportation mode, 2008

NAICS code	Transportation mode	Employees[1]	Payroll ($1,000) 1st quarter	Annual	Total firms
48----	**Transportation and warehousing**	**19,956**	**268,504**	**1,181,652**	**1,133**
481	**Air transportation**	**6,858**	**89,340**	**392,103**	**221**
48111	Scheduled	5,895	78,191	329,799	111
481111	Scheduled passenger	4,522	58,235	251,374	79
481112	Scheduled freight air transportation	1,373	19,956	78,425	32
48121	Nonscheduled	963	11,149	62,304	110
481211	Nonscheduled chartered passenger	628	5,975	37,806	93
481212	Nonscheduled chartered freight	c	D	D	6
481219	Other nonscheduled	137	2,120	8,410	11
483	**Water transportation**	**1,009**	**12,422**	**55,312**	**82**
48311	Deep sea, coastal, and great lakes	987	11,982	53,492	58
483111	Deep sea freight transportation	e	D	D	3
483112	Deep sea passenger	a	D	D	1
483113	Coastal and great lakes freight	f	7,461	33,888	49
483114	Coastal and great lakes passenger	4	S	165	5
48321	Inland water	b	440	1,820	24
483211	Inland water freight	a	D	D	9
483212	Inland water passenger	b	424	1,210	15
484	**Truck transportation**	**2,969**	**36,958**	**165,170**	**229**

[1]Paid employees for pay period including March 12 (number)

D: withheld to protect privacy (for quarterly/annual)
a: 0–19; b: 20–99; c: 100–249; e: 250–499; f: 500–999; g: 1000–2499; h: 2500–4999
Source: U.S. Census, http://censtats.census.gov/cgi-bin/cbpnaic/cbpdetl.pl

Table 22. Alaska transportation sector employment, payroll, and firms by transportation mode, 2010

NAICS code	Transportation mode	Employees[1]	Payroll ($1,000) 1st quarter	Payroll ($1,000) Annual	Total firms
48----	**Transportation and warehousing**	**17,974**	**256,733**	**1,118,746**	**1,113**
481	**Air transportation**	**5,845**	**75,818**	**320,111**	**207**
48111	Scheduled	4,901	64,742	257,983	102
481111	Scheduled passenger	4,106	49,940	201,292	71
481112	Scheduled freight air transportation	795	14,802	56,691	31
48121	Nonscheduled	944	11,076	62,128	105
481211	Nonscheduled chartered passenger	658	6,487	37,586	87
481212	Nonscheduled chartered freight	c	D	D	6
481219	Other nonscheduled	95	1,429	8,151	12
483	**Water transportation**	**1,312**	**14,754**	**70,749**	**93**
48311	Deep sea, coastal, and great lakes	1,289	14,594	67,730	64
483111	Deep sea freight transportation	c	D	D	3
483113	Coastal and great lakes freight	g	D	D	55
483114	Coastal and great lakes passenger	a	17	169	6
48321	Inland water	23	S	3,019	29
483211	Inland water freight	a	D	D	12
483212	Inland water passenger	a	71	1,055	17
484	**Truck transportation**	***2,530***	***28,590***	***136,415***	***225***

[1]Paid employees for pay period including March 12 (number)

D: withheld to protect privacy (for quarterly/annual)
a: 0–19; b: 20–99; c: 100–249; e: 250–499; f: 500–999; g: 1000–2499; h: 2500–4999
Source: U.S. Census, http://censtats.census.gov/cgi-bin/cbpnaic/cbpdetl.pl

Table 23. Change in Alaska transport sector employment, payroll, and firms, 2008–2010

NAICS code	Transportation mode	Employees[1]	Payroll ($1,000) 1st quarter	Payroll ($1,000) Annual	Total firms
48----	**Transportation and warehousing**	**-9.9%**	**-4.4%**	**-5.3%**	**-1.8%**
481	**Air transportation**	**-14.8%**	**-15.1%**	**-18.4%**	**-6.3%**
48111	Scheduled	-16.9%	-17.2%	-21.8%	-8.1%
481111	Scheduled passenger	-9.2%	-14.2%	-19.9%	-10.1%
481112	Scheduled freight air transportation	-42.1%	-25.8%	-27.7%	-3.1%
48121	Nonscheduled	-2.0%	-0.7%	-0.3%	-4.6%
481211	Nonscheduled chartered passenger	4.8%	8.6%	-0.6%	-6.5%
481212	Nonscheduled chartered freight	NA	NA	NA	0.0%
481219	Other nonscheduled	-30.7%	-32.6%	-3.1%	9.1%
483	**Water transportation**	**30.0%**	**18.8%**	**27.9%**	**13.4%**
48311	Deep sea, coastal, and great lakes	30.6%	21.8%	26.6%	10.3%
483111	Deep sea freight transportation	NA	NA	NA	-100.0%
483112	Deep sea passenger	NA	NA	NA	200.0%
483113	Coastal and great lakes freight	NA	NA	NA	12.2%
483114	Coastal and great lakes passenger	NA	NA	2.4%	20.0%
48321	Inland water			65.9%	20.8%
483211	Inland water freight	NA	NA	NA	33.3%
483212	Inland water passenger	NA	-83.3%	-12.8%	13.3%
484	**Truck transportation**	**-14.8%**	**-22.6%**	**-17.4%**	**-1.8%**

Source: U.S. Census, http://censtats.census.gov/cgi-bin/cbpnaic/cbpdetl.pl

Table 23 shows that between 2008 and 2010, employment in the transportation sector decreased by approximately 10%, with air transportation leading the decline at 15%. Most of the air decline was concentrated in scheduled freight transportation. The annual payroll decline in air transportation was 18%, again led by declines in scheduled freight transportation.

In contrast, employment in water transportation increased 30%, and trucking employment declined approximately 15%. These numbers reflect that the most energy-intensive transportation sectors experienced the largest decrease in employment. However, transportation services were also affected by the recession in addition to changes in crude oil prices.

Besides declines in employment and payroll, the number of firms decreased by 20, mostly in air transportation (Table 24 and Table 25). However, the number of water transportation firms increased, primarily in the smallest firm-size category. The increase in water transportation firms or businesses is likely the source of the employment increase shown in Table 27. Table 24 and Table 25 show the total number of firms, but not all firm-size classifications.

Table 24. Number of transportation industry firms by size, 2008*

		# of firms by employment-size class			
Industry code	Industry code description	Total #	'1-4'	'5-9'	'10-19'
48----	**Transportation and warehousing**	1,133	646	175	132
481	**Air transportation**	**221**	**96**	**34**	**35**
48111	Scheduled	111	23	16	25
481111	Scheduled passenger	79	16	7	19
481112	Scheduled freight air transportation	32	7	9	6
48121	Nonscheduled	110	73	18	10
481211	Nonscheduled chartered passenger	93	62	16	8
481212	Nonscheduled chartered freight	6	3	1	1
481219	Other nonscheduled	11	8	1	1
483	**Water transportation**	**82**	**55**	**11**	**8**
48311	Deep sea, coastal, and great lakes	58	32	11	7
483111	Deep sea freight transportation	3	1	0	0
483112	Deep sea passenger	1	1	0	0
483113	Coastal and great lakes freight	49	25	11	7
483114	Coastal and great lakes passenger	5	5	0	0
48321	Inland water	24	23	0	1
483211	Inland water freight	9	9	0	0
483212	Inland water passenger	15	14	0	1
484	**Truck transportation**	**229**	**130**	**33**	**28**

*Not a complete list of all size firms, but the total includes all firms of all sizes.

Source: U.S. Census, http://censtats.census.gov/cgi-bin/cbpnaic/cbpdetl.pl

Table 25. Number of transportation industry firms by size, 2010*

Industry code	Industry code description	Total #	'1-4'	'5-9'	'10-19'
		# of firms by employment-size class			
48----	**Transportation and warehousing**	1,113	655	160	121
481	**Air transportation**	**207**	**79**	**44**	**33**
48111	Scheduled	102	20	23	17
481111	Scheduled passenger	71	10	10	15
481112	Scheduled freight air transportation	31	10	13	2
48121	Nonscheduled	105	59	21	16
481211	Nonscheduled chartered passenger	87	50	17	14
481212	Nonscheduled chartered freight	6	2	2	1
481219	Other nonscheduled	12	7	2	1
483	**Water transportation**	**93**	**67**	**9**	**6**
48311	Deep sea, coastal, and great lakes	64	39	8	6
483111	Deep sea freight transportation	3	1	1	0
483113	Coastal and great lakes freight	55	32	7	6
483114	Coastal and great lakes passenger	6	6	0	0
48321	Inland water	29	28	1	0
483211	Inland water freight	12	12	0	0
483212	Inland water passenger	17	16	1	0
484	**Truck transportation**	**225**	**133**	**28**	**25**

*Not a complete list of all size firms, but the total includes all firms of all sizes.
Source: U.S. Census, http://censtats.census.gov/cgi-bin/cbpnaic/cbpdetl.pl

Using IMPLAN, we examine the sensitivity of the Alaska economy to the increase in transportation costs and fuel prices. We do this by passing cost increases to transportation consumers, which are households and industries that purchase transportation services. The input-output modeling methodology described earlier informs us regarding the transportation intensity of each sector. In input-output terminology, the model gives us the gross absorption of each of the transportation modes, which is simply the cents spent on that activity per dollar of output. Given that we also have the total output produced by each sector, we know the dollar amount that is spent by any given industry on transportation services. In the very short run, all else held constant, we simply analyze how the increase in transportation service prices would influence the sector's demand for inputs, which in this setting is equivalent to a decrease in value added, given that output is kept constant (see Appendix D for a glossary of economic impact terms).

Price increases are applied in the following way: We multiply the transportation sector's refined petroleum fuel-price increase times the share that refined petroleum fuel purchases represent per dollar of output for that transportation sector (Table 26). For example, if refined petroleum fuel products are 0.312 of each unit of output of air transportation, then a 29.16% increase in the price of refined petroleum fuel products results in a 9.1% increase in the cost of a unit of air transportation or:

$$0.312 * 0.2916 = 0.091$$

Thus, in this example of air transport, a 29.16% increase in jet fuel prices translates to a 0.091 increase in input costs for each unit of air transportation services output, or essentially an approximately 9% increase in costs. Table 26 shows these fuel price increases for each transportation mode based on U.S. EIA reported price increases between 2008 and 2010. We use these price increases in our impact simulation. The actual increase for each transportation subsector depends on the amount of fuel purchased. Table 26 shows these cost increases for all four subsectors.

Table 26. Alaska transportation services estimated price increase, 2008–2010

	Fuel price increase percentage (EIA)	Estimated price increase	Gross absorption coefficient (dollars spent on petroleum per dollar of output)
Air	29.16%	9.1%	0.312
Rail	29.17%	3.4%	0.131
Water	27.74%	7.4%	0.266
Truck	26.17%	3.9%	0.149

Sources: IMPLAN Input-Output Model; U.S. DOE, EIA; author calculations.

Before presenting the results, we show a list of the most transport-intensive industries (Table 27). In other words, these industries spend the largest portions per dollar of output on transportation services expenditures. The columns represent the cents per dollar of output being spent on these transport categories. We also show the transport share of the budget, which is simply the cents that are spent on transport as defined by the four sectors. Given that the Alaska economy had 257 sectors in 2008, we only list those that are the heaviest users in relation to their operation size. This list clearly does not show which industries are the biggest consumers of transportation services in absolute terms.

Table 27. Transportation usage intensity, 2008

Industry name	Air	Rail	Water	Truck	Transport share
Ready-mix concrete manufacturing	0.0029	0.0164	0.0032	0.1001	0.1227
Cut stone and stone product manufacturing	0.0051	0.0160	0.0027	0.0526	0.0764
Fertilizer manufacturing	0.0003	0.0111	0.0018	0.0607	0.0740
Office supplies (except paper) manufacturing	0.0019	0.0098	0.0009	0.0415	0.0541
Coffee and tea manufacturing	0.0033	0.0023	0.0035	0.0444	0.0536
Other animal food manufacturing	0.0011	0.0232	0.0039	0.0241	0.0523
Other pressed and blown glass and glassware manuf.	0.0020	0.0264	0.0018	0.0221	0.0523
Transport by truck	0.0025	0.0098	0.0008	0.0388	0.0518
Other aircraft parts and auxiliary equipment manuf.	0.0030	0.0056	0.0009	0.0399	0.0494
Scientific research and development services	0.0026	0.0010	0.0415	0.0032	0.0483
Mining coal	0.0002	0.0303	0.0021	0.0149	0.0475
Breweries	0.0011	0.0163	0.0007	0.0291	0.0472
Dog and cat food manufacturing	0.0007	0.0195	0.0022	0.0218	0.0442
Wood windows and doors and millwork manuf.	0.0027	0.0123	0.0001	0.0280	0.0430
Engineered wood member and truss manuf.	0.0034	0.0140	-	0.0254	0.0428
Mining and quarrying other nonmetallic minerals	0.0004	0.0096	0.0004	0.0302	0.0405
Jewelry and silverware manufacturing	0.0046	0.0016	0.0014	0.0328	0.0404
Snack food manufacturing	0.0016	0.0080	0.0022	0.0284	0.0401
Animal slaughtering and processing	0.0034	0.0010	0.0001	0.0355	0.0400
All other food manufacturing	0.0028	0.0069	0.0014	0.0274	0.0386
Mining and quarrying stone	0.0005	0.0040	0.0017	0.0323	0.0386
Fluid milk and butter manufacturing	0.0020	0.0016	0.0001	0.0343	0.0380
Concrete pipe, brick, and block manufacturing	0.0029	0.0096	0.0004	0.0240	0.0369
Sawmills and wood preservation	0.0010	0.0090	0.0000	0.0259	0.0360
US Postal Service	0.0130	0.0084	0.0059	0.0084	0.0357
Wineries	0.0020	0.0023	0.0016	0.0291	0.0351
Prefabricated wood building manuf.	0.0031	0.0082	-	0.0202	0.0314
Wood container and pallet manuf.	0.0028	0.0084	0.0002	0.0181	0.0295

Source: IMPLAN Input-Output Model, author calculations.

To apply the price shock, we simply increase each industry's expenditures on the respective transportation services by the percentages indicated in Table 26. Given that the various transportation services face different price increases, the cost increase faced by any given industry will depend upon the specific composition of the transportation services it consumes. We list the most affected industries in Table 28. We list these industries sorted according to the ones incurring the largest absolute increase in terms of their intermediate inputs expenditures on transportation services. We present the information in Table 28 in terms of value added lost as a result of the increase in the cost of transportation services that the industry purchases. The two presentations are equivalent given that:

$$\text{Intermediate Inputs} + \text{Value Added} = \text{Total Output}$$

Table 28. Value-added losses (most affected industries in absolute terms), millions$$

Industry			Value added		Refined petroleum as share of inputs
Code	Name	Value added	New	Decrease	
332	Transport by air	670.0	517.9	-152.1	31%
115	Petroleum refineries	120.0	57.5	-62.5	8%
17	Commercial fishing	110.0	70.6	-39.4	32%
334	Transport by water	160.0	121.2	-38.8	27%
337	Transport by pipeline	240.0	208.9	-31.1	21%
335	Transport by truck	300.0	277.7	-22.3	15%
339	Couriers and messengers	470.0	448.6	-21.4	12%
34	Construction of new commercial/health care	710.0	695.1	-14.9	4%
36	Construction of other new nonresidential structures	410.0	395.8	-14.2	6%
388	Services to buildings and dwellings	100.0	88.1	-11.9	22%
37	Construction of new residential housing	400.0	393.6	-6.4	3%
20	Extraction of oil and natural gas	2,000.0	1,994.0	-6.0	1%
319	Wholesale trade businesses	750.0	745.5	-4.5	1%
29	Support activities for oil and gas operations	1,500.0	1,495.8	-4.2	1%
39	Maintenance and repair of nonresidential structures	250.0	245.9	-4.1	4%
351	Telecommunications	1,000.0	996.0	-4.0	1%
333	Transport by rail	42.9	39.0	-3.8	14%
31	Electric power generation, transmission, distribution	640.0	636.7	-3.3	1%
369	Architectural, engineering, and related services	680.0	676.9	-3.1	1%
336	Transit and ground passenger transportation	65.0	62.0	-3.0	11%
61	Seafood product preparation and packaging	450.0	447.1	-2.9	0%
413	Food services and drinking places	790.0	787.2	-2.8	1%
	Subtotals and share of total	**11,857.9**	**11,401.1**	**-456.8**	**92%**

Source: IMPLAN Input-Output Model, author calculations.

The total of value added lost because of the transportation cost increase is $456.8 million. This loss in value added is equivalent to the additional cost of commodity inputs (in this case, higher transportation services). This presentation gives us a sense of the value-added losses that would be incurred by the industries that are the largest consumers of transportation services in absolute terms. This picture, however, does not provide us with information regarding the transportation intensity of these sectors.

An alternative way of examining the shock is to investigate the share of the industry's value added that would be lost as a result of the transportation cost increase. Table 29 lists the most sensitive industries; it shows the relative decrease in the sector's value added due to the transportation cost increases.

Note that the extent to which Alaska commodities, especially raw materials, are extracted and exported by foreign companies using foreign shipping fleets affects the calculation. These transportation service values are not included in this exercise because such transactions are not part of the Alaska economy. For example, if a Canadian mining company extracts ore and ships it to Canada or Asia for smelting, the payment for the ore, including the cost of shipping, does not enter the Alaska economy. Instead, the payment is received in Canada and reflected in Canadian regional economic accounting. If the payment for shipping is a separate transaction but paid to a foreign shipper, this transaction similarly would not be reflected in the Alaska regional economy. To the extent that shippers purchase fuel in Alaska, these fuel purchase transactions would be part of the Alaska regional economy as well as the emissions resulting from the fuel purchased in Alaska.

Table 29. Value-added losses (most affected industries relative to own value added)

Industry code	Industry name	Value added
66	Coffee and tea manufacturing	-3.40%
130	Fertilizer manufacturing	-2.49%
42	Other animal food manufacturing	-2.26%
91	Apparel accessories and other apparel manufacturing	-2.06%
347	Sound recording industries	-2.01%
59	Animal (except poultry) slaughtering and processing	-1.97%
72	Wineries	-1.92%
310	Jewelry and silverware manufacturing	-1.76%
161	Ready-mix concrete manufacturing	-1.75%
70	Soft drink and ice manufacturing	-1.62%
138	Soap and cleaning compound manufacturing	-1.53%
65	Snack food manufacturing	-1.52%
71	Breweries	-1.33%

Source: IMPLAN Input-Output Model, author calculations.

This exercise examines the very short-run implications of a price increase in transportation services if the consuming industries were to continue using the same amounts of commodity input and no other behavioral responses were to occur. It is clear the sensitivity varies greatly from one sector to the next and that different metrics yield different rankings.

To assess the impact of these increases on actual usage, we look at what happened to transportation usage by mode between 2008 and 2010. Before looking at usage of the different industries, we examine an aggregate picture (Table 30).

Table 30. Change in institution and industry commodity demand for transportation services between 2008 and 2010

Commodity Demand	2008	2010	2008$	% Change
Rail				
Institution	$141,582,592	$144,231,376	$136,582,742	-4%
Industry	$76,224,520	$61,473,528	$58,213,568	-24%
All	$217,807,112	$205,704,904	$194,796,311	-11%
Air				
Institution	$1,855,906,304	$1,521,707,008	$1,481,701,079	-20%
Industry	$92,350,312	$94,027,944	$91,555,934	-1%
All	$1,948,256,616	$1,615,734,952	$1,573,257,013	-19%
Water				
Institution	$523,841,536	$510,785,344	$458,103,448	-13%
Industry	$25,166,378	$6,796,376	$6,095,404	-76%
All	$549,007,914	$517,581,720	$464,198,852	-15%
Truck				
Institution	$441,049,024	$356,745,728	$348,725,052	-21%
Industry	$317,363,488	$267,229,648	$261,221,552	-18%
All	$758,412,512	$623,975,376	$609,946,604	-20%

Institution demand, or final demand as it is sometimes called, is demand for goods and services for final use. Final use means that the goods or service will be consumed and not incorporated into another product. In contrast, industry commodity demand is the intermediate use of a good or service to produce another good or service. An example would be the tourism industry purchasing air transportation services as part of a tour package. Commodity demand is the amount of purchases of transportation services by institutions (final purchases) and industry (intermediate purchases as inputs to production).
Source: IMPLAN Input-Output Model for Alaska (2008–2010) and author calculations.

The aggregate picture presented in Table 30 makes clear that the demand for transportation decreased along with economic conditions, including the major recession. However, the magnitude of the decrease is not consistent across the four sectors. Also, institutional demand decreased for transport by air, while demand by industries was flat; on the other hand, we see that demand by industries for transportation by water has taken a sharp decrease. However, industry commodity demand for water transportation is only 5% of total water transportation demand.

Next, we examine how transportation-related expenditures have changed for the different sectors.

Using IMPLAN data for 2008 and 2010, we look at how expenditures on different transportation modes shifted for a given industry by following these steps:

- First, we generate transportation dollars for years 2008 and 2010, which are comprised of the expenditures made by the different sectors on air, water, rail, and truck transportation services.

- Second, we generate shares that these different transportation sectors comprise from the overall transport dollars.
- Third, we compare how the allocation of transportation dollars shifted between 2008 and 2010.

By comparing the shares across years, we get an idea, for example, if air transportation represents a bigger or smaller share of the overall transportation dollars in the Alaska economy.

Before showing the changes, we list the industries with the highest absolute transportation expenditures and the share those expenditures represent of their total output (Table 31).

Table 31. Alaska industries with largest transportation expenditure inputs, 2008, million$$

Code	Industry Name	Output	Transport	Share
61	**Seafood product preparation and packaging**	$3.3	$67.3	0.0204
29	**Support activities for oil and gas operations**	$2.8	$46.0	0.0164
335	**Transport by truck**	$570.0	$29.5	0.0518
28	**Drilling oil and gas wells**	$920.0	$18.2	0.0198
34	**Construction of new nonresidential commercial and health care structures**	$1,500.0	$17.4	0.0116
37	**Construction of new residential single-/multi-family**	$870.0	$16.1	0.0185
31	**Electric power generation, transmission, distribution**	$840.0	$14.8	0.0176
24	**Mining gold, silver, and other metal ore**	$1,200.0	$13.2	0.0110
413	**Food services and drinking places**	$1,500.0	$12.1	0.0081
432	**Other state and local government enterprises**	$1,100.0	$11.9	0.0108
36	**Construction of other new nonresidential structures**	$860.0	$11.0	0.0128
351	**Telecommunications**	$2,300.0	$10.2	0.0044
71	**Breweries**	$220.0	$10.2	0.0464
161	**Ready-mix concrete manufacturing**	$81.0	$9,.9	0.1227
332	**Transport by air**	$1,800.0	$8,.5	0.0047
115	**Petroleum refineries**	$3,100.0	$8.2	0.0026

Source: IMPLAN Input-Output Model, author calculations.

Table 32 shows the mode shifts between 2008 and 2010 for sectors with the highest transport expenditures. The changes are calculated using the following formula:

Change Air = (ShareAir2010 –ShareAir2008)/ (ShareAir2008)

Table 32. Mode shifts for Alaska industries with largest transportation expenditure inputs following imposed fuel price increases

		Change			
Industry Name	**Code**	**Air**	**Rail**	**Water**	**Truck**
Seafood product preparation and packaging	61	0.036	-0.017	None	-0.109
Support activities for oil and gas operations	29	0.012	-0.041	-0.748	-0.337
Transport by truck	335	0.090	0.033	-0.729	-0.145
Construction of other new nonresidential structures	36	0.108	0.051	-0.724	1.129
Other state and local government enterprises	432	0.391	0.319	-0.656	0.003
Food services and drinking places	413	0.041	-0.014	-0.74	-0.081
Petroleum refineries	115	0.995	0.885	-0.506	0.531
Electric power generation, transmission, distribution	31	-0.207	-0.249	-0.804	-0.355
Mining gold, silver, and other metal ore	24	-0.143	-0.191	-0.788	-0.240
Maintenance/repair/construction nonresidential structures	39	0.401	0.328	-0.652	0.870
Construction of other new residential structures	38	0.046	-0.008	-0.74	1.136
Monetary/depository credit intermediation activities	354	0.945	0.818	-0.523	1.532
Offices of physicians, dentists, other health practitioners	394	0.260	0.193	-0.691	0.293
Ready-mix concrete manufacturing	161	0.105	0.047	-0.726	-0.277
Telecommunications	351	-0.214	-0.254	-0.807	-0.357
Construction of new nonresidential commercial and health care structures	34	-0.043	-0.093	-0.764	-0.618

A complete listing of all the industries mode shifts is available upon request.
Source: IMPLAN Input-Output Model, author calculations.

In looking at this information, it is important to note that the demand for any given commodity (for example, water transportation) is comprised of industrial and institutional consumption. Institutional consumption (or final consumption as opposed to industry consumption for the production of a final product) includes nine different household income groups, government, and domestic and foreign exports.

Within demand for water transportation, the pattern was not consistent. Industrial demand declined (-76%). The change in institutional demand was more complicated, with the demand for exports to foreign countries increasing considerably and the demand for exports to the U.S. markets declining similarly. Further analysis shows that industrial demand for water transportation decreased significantly. Table 33 shows a breakdown of transport demand between industry and institutions; it also shows the demand for water transportation in both years (2008 and 2010) and how the subcomponents of institutional demand changed. We are uncertain of the drivers of these demand shifts, but note that most smelting of ores extracted from Alaska occurs in export locations, and mineral prices continued to increase during this period. In addition, domestic oil shipments from Valdez to refineries in the Lower 48 decreased by four million short tons between 2008 and 2010, reflecting the continued reduction in North Slope oil production (U.S. Army Corps of Engineers, 2012a, b).

Table 33. Institution and industry demand for water transportation, 2008 and 2010 (2008$)

	2008	2010	% change
Institution Demand	$523.8	$458.1	-13%
Foreign Exports	$191.1	$335.1	75%
Domestic Exports	$275.8	$92.3	-67%
Industry Demand	$25.2	$6.1	-76%
Total Demand	$547.9	$464.1	-15%

Source: IMPLAN Input-Output Model, author calculations.

Impact of Change in Transportation Costs on Alaska Households

We apply the same transport price increases to households as we do to industry—by multiplying the mode's price increase times the share that refined petroleum purchases represent per dollar of output (see Table 26 for details). Nine household income categories are in our model, and they all consume transportation services, which now cost more as a result of the price shock imposed; this is the same price increase faced by industries, as discussed earlier. The changes for households reflect direct and indirect consumer purchases of transportation services. For example, an apple purchased at a grocery store includes imbedded transportation services that include shipping from its origin in the orchard to the grocery store shelves. The scenario presented in Table 34 assumes that these household groups will continue consuming the same amounts of transportation services at their higher price to infer how much "income loss" would be incurred after the price increases. Transportation dollars are once again comprised of dollars spent on air, rail, truck, and water transportation services (Table 34).

Table 34. Increases in the cost of transportation services to households by income groups after an increase in the price of refined petroleum products, millions$$

	Direct household expenditures on transportation services							
All households with incomes of:	**Air**		**Rail**		**Water**		**Truck**	
	Before	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
less than $10,000	$6.7	$7.3	$0.1	$0.1	$0.1	$0.1	$3.8	$3.9
$10,000-$14,999	$3.5	$3.9	$0.3	$0.3	$0.2	$0.2	$3.0	$3.1
$15,000-$24,999	$8.9	$9.7	$1.3	$1.3	$0.7	$0.7	$10.7	$11.1
$25,000-$34,999	$10.7	$11.7	$1.4	$1.4	$0.7	$0.8	$9.8	$10.2
$35,000-$49,999	$23.0	$25.0	$1.2	$1.3	$1.3	$1.4	$19.6	$20.3
$50,000-$74,999	$36.0	$39.3	$3.7	$3.9	$4.1	$4.4	$28.8	$29.9
$75,000-$99,999	$27.9	$30.5	$2.3	$2.4	$2.5	$2.6	$27.1	$28.2
$100,000-$149,999	$38.4	$41.9	$2.8	$2.9	$3.0	$3.2	$27.9	$29.0
$150,000+	$47.1	$51.4	$3.5	$3.6	$3.5	$3.7	$38.5	$40.0
Total	$202.3	$220.8	$16.7	$17.2	$16.0	$17.2	$169.1	$175.7
Increase cost to households		$18.4		$0.6		$1.2		$6.6

Source: IMPLAN Input-Output Model, author calculations.

The total effect on households would be equivalent to a loss of income equaling $26.8 million (Table 35). This "loss" is simply the first-order decrease in income available for household purchases as a result of the increase in prices of transportation services. The table shows that among households at almost every income level, the increase in spending for transportation services after the imposed price increase is approximately the same percentage (6% to 7%).

Table 35. Increases in the cost of air, rail, water, and truck transportation services to households by income groups after an increase in the price of refined petroleum products, millions$$

All households	Direct household expenditures on transportation services			
with incomes of:	**Before**	**After**	**Difference**	**Share of change**
less than $10,000	$10.7	$11.5	$0.8	3%
$10,000-$14,999	$7.0	$7.4	$0.5	2%
$15,000-$24,999	$21.6	$22.9	$1.3	5%
$25,000-$34,999	$22.6	$24.1	$1.5	5%
$35,000-$49,999	$45.0	$48.0	$3.0	11%
$50,000-$74,999	$72.6	$77.5	$4.8	18%
$75,000-$99,999	$59.8	$63.7	$3.9	14%
$100,000-$149,999	$72.1	$77.0	$4.9	18%
$150,000+	$92.6	$98.7	$6.2	23%
Total	$404.1	$430.8	$26.8	

Source: IMPLAN Input-Output Model, author calculations.

The increases in transportation service costs or equivalent "household income losses" in Table 34 depict the assumption that all households continue to consume the same level of transportation services even after the price increases. Table 35 shows two types of information: (1) how much more those services would cost based on the transportation-services consumption patterns of specific household income groups, and (2) the share of increase in cost of transportation services that each household income group would absorb of the total cost increases. Table 34 shows how these increased costs would be spread across the air, rail, water, and trucking sectors. Again, these figures are the total amount each household income group would pay for transportation services by mode following increases in the cost of these services and assuming no change in rate of consumption. The cost increases result from an increase in the price of refined petroleum products.

In contrast, Table 36 shows how the allocation of transportation dollars would shift for different household income groups if we remove the assumption that they will continue to consume transportation services at the same rate as before the price increase. This exercise simply examines how the shares of each sector change because of price increases imposed for transportation services; it reflects actual cost changes between 2008 and 2010. The changes in Table 36 also include the reduction in consumer purchasing that resulted from the recession.

Table 36. Shift in household purchases of air, rail, water, and truck transportation services due to increases in the cost of transportation services

All households with incomes of:	Air	Rail	Water	Truck
less than $10,000	14.8%	-35.3%	-43.3%	-23.4%
$10,000-$14,999	20.9%	-31.9%	-40.3%	-19.3%
$15,000-$24,999	27.9%	-44.6%	-51.4%	-14.6%
$25,000-$34,999	23.0%	-30.7%	-39.2%	-17.9%
$35,000-$49,999	20.6%	-32.1%	-40.4%	-19.5%
$50,000-$74,999	22.4%	-31.1%	-39.5%	-18.4%
$75,000-$99,999	23.2%	-30.6%	-39.1%	-17.8%
$100,000-$149,999	20.0%	-32.4%	-40.7%	-20.0%
$150,000+	21.0%	-31.8%	-40.2%	-19.2%

Source: IMPLAN Input-Output Model, author calculations.

In Table 37 we show how much more households, by income groups, would pay directly for refined petroleum products (primarily diesel and gasoline) due to fuel price increases if we assume that they continue to consume at the same levels before and after the price increases. These dollar amounts are the increases in household expenditures for refined petroleum products purchased by the household directly, such as gasoline for personal vehicles, rather than transportation services. Utilities are not included, so the calculation does not encompass things such as natural gas for space heating or electricity, or diesel to produce electricity. Under this scenario related to direct household income group purchases of refined petroleum products, the increase in costs to households, or the equivalent loss of income, amounts to approximately $124 million.

Table 37. Increases in household expenditures due to an increase in the cost of refined fuel prices, millions$$

Direct household expenditures on refined petroleum products						
				Share of:		
All households	Expenditures			Statewide	Household budget	
with incomes of:	Before	After	Difference	change	Before	After
less than $10,000	$10.4	$13.3	$2.9	2%	2.2%	2.8%
$10,000-$14,999	$8.9	$11.4	$2.5	2%	1.9%	2.4%
$15,000-$24,999	$28.9	$36.8	$7.9	6%	2.5%	2.4%
$25,000-$34,999	$31.4	$40.1	$8.7	7%	2.0%	2.6%
$35,000-$49,999	$52.4	$66.9	$14.5	12%	1.9%	2.4%
$50,000-$74,999	$99.5	$127.1	$27.6	22%	1.9%	2.4%
$75,000-$99,999	$75.3	$96.1	$20.8	17%	1.8%	2.3%
$100,000-$149,999	$81.6	$104.3	$22.7	18%	1.8%	2.2%
$150,000+	$59.5	$76.0	$16.5	13%	1.4%	1.7%
Total	$447.9	$572.0	$124.1			

Source: IMPLAN Input-Output Model, author calculations.

Carbon Emissions Analysis

Because a carbon emissions tax has a similar effect as a price increase, we also assessed the potential effects of such a tax. To explore the potential impact of an emissions tax on transportation sector output and employment, we first examine the direct emissions from fuel use for the various transportation modes and then analyze the potential impact of an emissions tax.

Direct Emissions from Fuel Use

Table 38 and Figure 16 provide an estimate of CO_2 emissions by mode for the years 2007 to 2010. These emissions estimates are solely for the direct fuel used by the various modes and do not include fuel and emissions in ports, rail yards, or airports. The emissions estimates also do not include "imbedded" fuel use and emissions by the industry sector as a whole, such as heating and lighting of buildings and other energy uses. As a result, these emissions estimates are a subset of our industry analysis of emissions and the potential effects of an emissions tax.

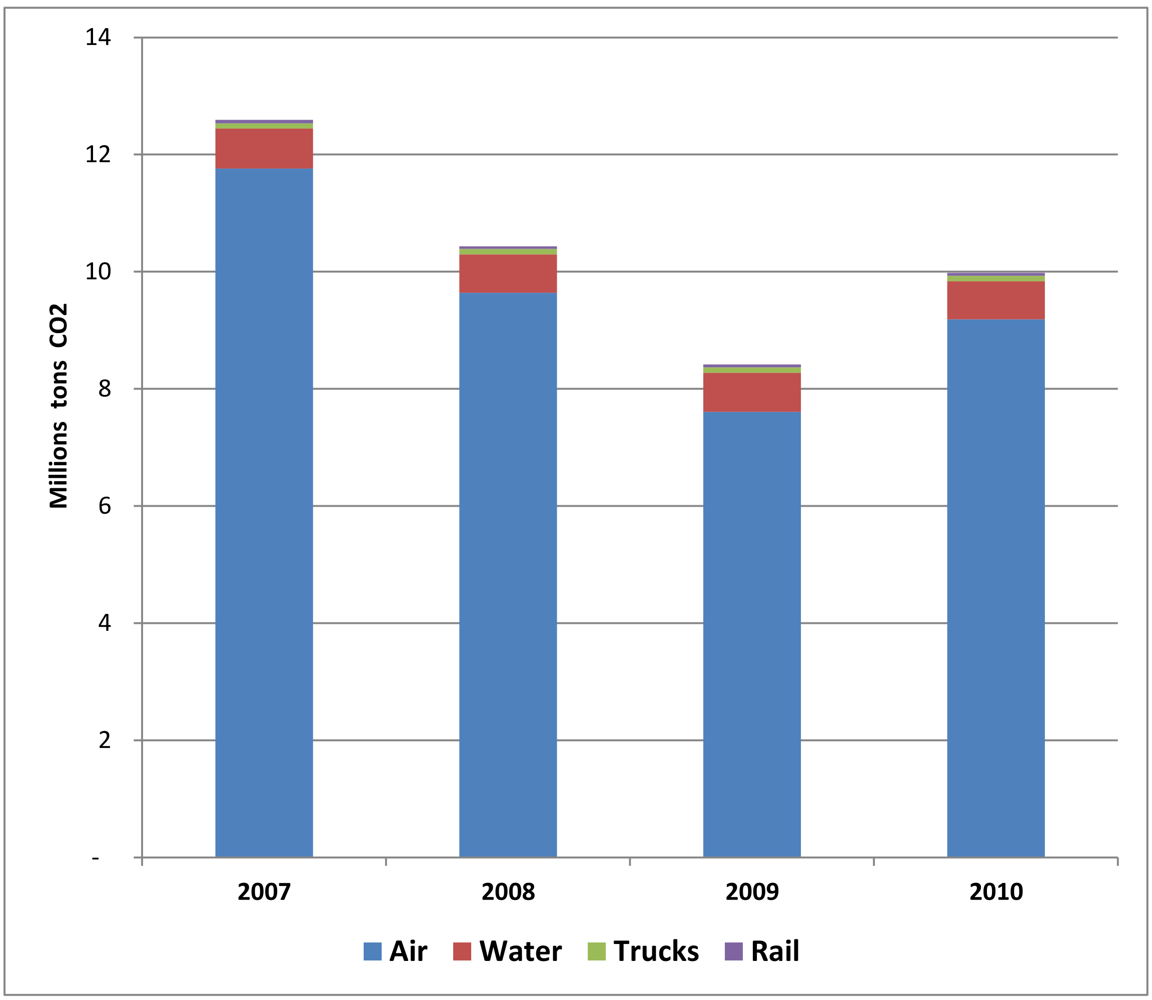


Figure 16. Comparison of annual emissions by transportation sector, intrastate and exiting only, 2007–2010
Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Waterborne Statistics; AMHS; AKRR; IFA; company proprietary information; author calculations.

Table 38. Estimated aviation, shipping, trucking, and rail emissions, Alaska 2007–2010

		2007	2008	2009	2010
Aviation					
Scheduled intra-state		**2007**	**2008**	**2009**	**2010**
gallons		30,684,229	31,457,698	27,330,122	27,846,200
CO_2 emissions [mt]		*293,587*	*300,987*	*261,495*	*266,432*
Non-scheduled intra-state					
gallons		5,963,125	9,301,368	6,732,250	7,859,375
CO_2 emissions [mt]		*57,055*	*88,995*	*64,414*	*75,199*
Exiting (scheduled & non-scheduled)					
gallons		1,193,994,646	967,954,934	762,383,628	925,632,425
CO_2 emissions [mt]		*11,411,037*	*9,250,826*	*7,283,021*	*8,847,839*
Entering (scheduled & non-scheduled)					
gallons		1,207,421,777	982,127,718	772,386,783	934,194,928
CO_2 emissions [mt]		*11,539,361*	*9,386,276*	*7,378,581*	*8,929,685*
Aviation total: gallons		2,438,063,777	1,990,841,718	1,568,832,783	1,895,532,928
CO_2 emissions [mt]		*23,301,040*	*19,027,084*	*14,987,511*	*18,119,155*
Alaska CO_2 emissions [mt]		*11,761,679*	*9,640,808*	*7,608,930*	*9,189,470*
Water					
Barges/Ships gallons		95,383,724	94,056,619	95,190,267	91,307,812
	gal. (intra-state & exiting)	78,243,753	77,260,621	78,012,015	73,839,840
	CO_2 emissions [mt]	*825,389*	*814,822*	*823,256*	*781,901*
Ferries	**gal. (intra-state & exiting)**	11,946,490	10,455,345	10,150,310	10,450,611
	CO_2 emissions [mt]	*109,558*	*97,318*	*93,304*	*96,065*
Total Water	**gallons**	107,330,214	104,511,963	105,340,577	101,758,423
	CO_2 emissions [mt]	*934,947*	*912,140*	*916,560*	*877,966*
Trucks (only one year of data)					
	gallons	9,800,000	9,800,000	9,800,000	9,786,844
	gallons (intra-state & exiting)	8,900,000	8,900,000	8,900,000	8,805,455
	CO_2 emissions [mt]	*90,335*	*90,335*	*90,335*	*89,375*
Railroad					
	gallons (freight)	4,342,932	3,241,907	3,618,137	3,993,404
	CO_2 emissions [mt]	*44,081*	*32,905*	*36,724*	*40,533*
	gallons (passengers)	1,220,758	1,228,142	1,195,411	1,149,241
	CO_2 emissions [mt]	*12,391*	*12,466*	*12,133*	*11,665*
Total rail	**gallons**	5,563,690	4,470,049	4,813,548	5,142,645
	CO_2 emissions [mt]	*56,471*	*45,371*	*48,858*	*52,198*
Total Alaska CO2 emissions [mt]		***12,843,433***	***10,688,654***	***8,664,682***	***10,209,009***

Notes: Numbers in black are directly from the BTS and EIA data. Blue numbers were calculated from BTS, EIA data and other proprietary data sources. Total weight includes freight, mail, and passengers. Aircraft type numbers are T100 data codes. Fuel prices in blue are estimates based on OPIS price data and limited proprietary data provided.
Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Waterborne Statistics; AMHS; AKRR; IFA; company proprietary information; author calculations.

Despite this lack of precision, we can see that CO_2 emissions from barges and ships range from about 10% to 15% per ton-mile of freight carried, as compared with ferries (Table 39). The Alaska Railroad emissions are about 20% of that from trucks, per ton-mile transported (Table 40). The railroad moves passengers at approximately half the per passenger-mile emissions of the national estimate for aviation and about 10% of the estimate for ferries (Table 41). The per passenger-mile carbon emissions of ferry transportation is, on average, about five times greater than the national estimate for air passenger transportation (without an aviation emissions multiplier), likely as a result of the Alaska Marine Highway System's low capacity factor and passenger-miles per gallon of fuel. Emission multipliers are used for aviation because the impacts of emissions are greater at altitude (Jardine, 2009). These emissions multipliers range in value from 1.9 to 4, depending on the emissions calculator and studies (Jardine, 2009). Use of an emissions multiplier reduces this difference, but air transportation emissions per passenger-mile still remain below the transportation emissions of ferries (Table 41). Estimates of aviation emissions with and without an emissions multiplier are shown in Table 41.

Table 39. Estimated water transportation ton-miles per gallon and fuel costs and emissions per ton-mile transported, Alaska 2007–2010, 2011$

	Water		
	Barges	**Ships**	**Ferries**
Average ton-miles per gallon of fuel	186	146	19
Average fuel costs per ton-mile	$0.016	$0.021	$2.37
CO_2 emissions per ton-mile (kilograms)	0.05	0.08	0.53

Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Waterborne Statistics; AMHS; IIFA; company proprietary information; author calculations.

Table 40. Comparison of estimated land transportation modes ton-miles per gallon and fuel costs and emissions per ton-mile transported, Alaska 2007–2010, 2011$

	Railroad	**Trucks**
Average ton-miles per gallon of fuel	279	48
Average fuel costs per ton-mile	$0.01	$0.06
CO_2 emissions per ton-mile (kilograms)	0.04	0.21

Sources: U.S. DOT, BTS; U.S. DOE, EIA; AKRR; company proprietary information; author calculations.

Table 41. Comparison of estimated passenger transportation modes passenger-miles per gallon and fuel costs and emissions per passenger-mile transported, Alaska 2007–2010, 2011$

	Railroad	**Ferry**	**Air***
Average passengers-miles per gallon of fuel	120	12	50
Average fuel costs per passengers-mile	$0.02	$3.83	$0.09
CO_2 emissions per passenger-mile (kilograms)	0.08	0.85	0.19
CO_2/passenger-mile w/aviation multiplier	0.08	0.85	0.56

*U.S. average for comparison purposes only. Show with and without aviation emissions multiplier.
Sources: U.S. DOT, BTS; U.S. DOE, EIA; U.S. Army Corps of Engineers, Waterborne Statistics; AMHS; IFA; Jardine, 2009; Ingram, 2008; company proprietary information; author calculations

Carbon Emissions Tax Analysis

This section analyzes the potential impact of a carbon tax on Alaska industries and the air, water, rail and trucking transportation sectors. By using IMPLAN, we capture not only the direct fuel use of an industry but also the embedded energy intensity of all industry inputs. We do not analyze a specific tax proposal, since none is currently pending. Instead, we show the relative impact of a tax on carbon emissions on the four transportation sectors analyzed. (U.S. EPA, 2006; Schipper, Unander, Murtishaw, Ting, 2001)

A carbon tax structured to decrease carbon emissions usually works by providing incentives for industries and households to adjust behavior by substituting away from the most carbon intensive products. This shift occurs because the prices of these products rise proportionately more than less-intensive ones. The carbon intensity of any given product is largely driven by the types of fossil fuels used in its production and by suppliers (Table 42).

Table 42. Industry sectors most impacted by a potential carbon emissions tax

Energy Rank	IMPLAN sector name	IMPLAN Sector #	CO_2 intensity	"Tax"
			Per unit of output	
1	Petroleum refineries	115	0.1039	0.0104
2	Natural gas distribution	32	0.0698	0.0070
3	State and local government electric use	431	0.0452	0.0045
4	Asphalt paving mixture and block manuf.	116	0.0398	0.0040
5	State and local government passenger	430	0.0391	0.0039
6	Other basic chemical manufacturing	126	0.0370	0.0037
7	Transport by pipeline	337	0.0268	0.0027
8	Plastics material and resin manufacturing	127	0.0265	0.0026
9	Commercial fishing	17	0.0240	0.0024
10	Transport by air	332	0.0232	0.0023
11	Fertilizer manufacturing	130	0.0173	0.0017
12	Services to buildings and dwellings	388	0.0167	0.0017
13	Electric power generation transmission	31	0.0154	0.0015
14	Other state and local government enter.	432	0.0139	0.0014
15	Transport by truck	335	0.0120	0.0012
16	All other crop farming	10	0.0115	0.0011
17	All other chemical product and prep.	141	0.0111	0.0011
18	Toilet preparation manufacturing	139	0.0099	0.0010
19	Couriers and messengers	339	0.0094	0.0009
20	Extraction of oil and natural gas	20	0.0091	0.0009
21	Transit and ground passenger transp.	336	0.0083	0.0008
22	Cattle ranching and farming	11	0.0072	0.0007
23	Transport by rail	333	0.0068	0.0007

Source: IMPLAN Input-Output Model, U.S, DOE, EIA, author calculations.

To analyze the impact of a carbon dioxide tax on the transportation sectors of the Alaska economy, we used energy use estimates from the U.S. Department of Energy, Energy Information Administration, State Energy Data System (U.S. DOE, EIA, SEDS, 2012a) along with IMPLAN data on types of fuel and fuel usage intensity. The respective “tax rate” is based on the relative carbon dioxide intensity of the industry or service.

From the EIA, SEDS information, we obtained the statewide fuel consumption in Btus for diesel fuel, jet fuel, and residual fuel oil (U.S. DOE, EIA, 2012a). We used the IMPLAN statewide output to generate the Btus per dollar of output from which we generate industry/fossil fuel specific Btus per dollar of output. This result becomes the matrix of energy requirements in Btus for the transportation sectors based on their use of fossil fuels; this matrix provides an estimate of the energy requirements per unit of output/demand. This method is more comprehensive than simply applying a carbon tax to direct fuel usage, as it also includes energy used in production (Creedy and Sleeman, 2004a, b, 2005).

Table 43. Transportation sector fuel use and emissions by industry output

	mmBtu	Output (millions $$)	mmBtu/$ of output	(mmBtu/$) * emissions factor	kg CO_2/ per unit of output	"Tax"	Tax w/air multiplier
Air	25,247,402	$1,817.4	0.014	0.985	1.541	0.0015	0.0045
Rail	471,216	$112.0	0.004	0.308	0.445	0.0004	0.0004
Truck	2,728,583	$569.0	0.005	0.351	0.488	0.0005	0.0005
Water	11,118,997	$541.7	0.021	1.617	2.491	0.0025	0.0025

Source: IMPLAN Input-Output Model, U.S, DOE, EIA, author calculations.

The calculated "tax" is the relative "tax" increase per unit of output, based on the carbon intensity of a unit of production of output. The highest kilogram of CO_2 per unit of output is for water transportation followed by air, truck, and rail. The relatively higher carbon intensity of water transportation per unit of output as compared with air transportation per unit of output results primarily from the comparative advantage of air transportation's higher value output per energy input (see column headed "mmBtu/$ of output" in Table 43). However, this initial result does not include an aviation emissions multiplier. As just discussed, these multipliers range from 1.9 to 4 for each kilogram of carbon emissions (Jardine, 2009). If an average multiplier of 2.9 is applied to the air carbon intensity per unit of output, the relative "tax" on air transportation is 0.0045, or 1.8 times greater than the comparative tax on water transportation. Therefore, a carbon tax would have a relatively higher impact per unit of output for air transportation than for water transportation following the imposition of an air emissions multiplier.

Given that the different transport sectors face different taxes, the consuming sectors would also face a varying additional burden, depending upon how much of each of these services they consume. It is noteworthy that while some sectors may not be large consumers of transport relative to the overall scale of the economy, the expenditures geared toward transport are a significant portion of their outlay. Therefore, the transport usage intensity—not just the dollar outlay—should be taken into account when considering such measures.

Energy used in production calculation method:

The intensity is defined by c_i, which measures the kilograms of carbon dioxide emissions per final consumption of the output from industry (i). Therefore a carbon dioxide tax of α, which is placed on carbon dioxide emissions, is equivalent to an ad valorem tax exclusive tax rate on the i_{th} commodity group τ_i , where[1]

$\tau_i = \alpha c_i$

As the intensity is expressed in terms of each dollar's worth of the output that contributes to final demands, the total amount of carbon dioxide arising from all industries, *E,* is given by

$E = \sum_{i=1}^{n} c_i y_i = c'$y

where yi is the value of final demand for industry *i* for *i* =1, *n.* The terms *c* and *y* denote corresponding column vectors, and the prime indicates transposition. The carbon dioxide intensities depend in a direct way on the types and amounts of fossil fuels used by each industry and the emissions per unit of those fossil fuels. However, the problem is complicated by the need to consider the total output of each industry, rather than merely the amount of that output which is consumed, that is the final demand.

Alaska fuel usage, expenditures, and intensity:

Calculations and variables:

e' the k-element vector of CO_2 emissions (kg of carbon dioxide) per unit of energy (Btu) associated with each of the *k* fossil fuels.

k fuels: Diesel fuel, Jet Fuel, Residual

F' n*k matrix matrix of energy requirements in Btus for *n* industries (transport) across *k* fuel types

n number of industries (transport)

k fuels

** Multiplying the transpose of the *e* vector by the transpose of the *F* matrix gives a row vector, which contains the carbon dioxide emissions per unit of gross output from each industry:

$c' = e'F'((I - A)^{-1})$ Carbon dioxide intensities

where $(I - A)^{-1})$ is the total requirement matrix.

E Total carbon dioxide emissions (not comprehensive but as defined by the *k* fuels

[1] For further exposition, see Creedy, J., and Sleeman, C. (2004b) Carbon Dioxide Emissions Reductions in New Zealand: A Minimum Disruption Approach. New Zealand Treasury and Creedy, J., and Sleeman, C. (2004a) Carbon Taxation, Prices and Household Welfare in New Zealand.

$E = (e'F'((I - A)^{-1})$*Y

Y: final demand

α: ad hoc tax in this case 10$ per kg on carbon dioxide emissions

Tau(i) : $\tau_i = \alpha c_i$

which refers to the ad valorem tax exclusive rate on the i_{th} commodity group tau i.

From the EIA, SEDS information, we obtained the statewide fuel consumption in Btus for diesel fuel, jet fuel, and residual fuel oil. We used the IMPLAN statewide output to generate the Btus per dollar of output from which we generate an industry/fossil fuel-specific Btus per dollar of output. This calculation becomes our $n * k$ matrix of energy requirements in Btus for *n* transport industries across *k* fossil fuels, which provides an estimate of the energy requirements per unit of output/demand of the Alaska economy. This method is more comprehensive than simply applying a carbon tax to direct fuel usage.

Consider increasing the final consumption of a good by $1. The problem is to evaluate how much carbon dioxide this would involve. This increase in the final demand by $1 involves a larger increase in the gross, or total, output of the good, as well as requiring increases in the outputs of other goods, because intermediate goods, including the particular good of interest, are needed in the production process. The extent to which there is an increase in carbon dioxide depends also on the intermediate requirements of all goods, which are themselves intermediate requirements for the particular good. Indeed, the sequence of intermediate requirements continues until it “works itself out,” such that the additional amounts needed become negligible. This is in fact a standard multiplier process.

$c' = e'F'((I - A)^{-1})$

This expression can then be used together with a selected carbon tax rate to calculate the effective carbon tax rates given by the following equation:

$\tau_i = \alpha c_i$

This analysis uses the industry input matrix of the IMPLAN software to account for the use of energy in the Alaska economy. In this way, we estimate both the fuel use and energy intensity per unit of output of final demand in the Alaska economy. Naturally, the most transport-intensive commodities are the ones that face the highest “tax” increase.

Conclusions

In this analysis, we estimated energy and fuel use by Alaska transportation sectors to understand impacts of sudden increases in fuel price or an emissions tax on the transportation sectors and the Alaska economy. Results of our analysis indicate that Alaska major industries are most vulnerable to fuel price shocks. Alaska households are impacted directly and indirectly because most goods are shipped long distances to Alaska. We found that the inability to collect accurate data seriously hampered our ability to conduct this analysis. Even publically available data such as the BTS datasets are not constructed or cross-referenced in a way that permits comprehensive regional fuel use, energy, and emissions analyses.

We estimated the energy and fuel used by the air, water, trucking, and rail transportation sectors in Alaska. We compared their fuel intensity to move passengers and freight by estimating their passenger-miles per gallon of fuel, ton-miles per gallon of fuel, and fuel costs per passenger-mile and per ton-mile.

We estimated that rail is the most efficient form of transportation for moving freight per gallon of fuel, followed by barge, marine ship, truck, and ferry. In estimating passenger-miles per gallon of fuel, we found again that rail transport is the most fuel-efficient, followed by air and ferry. Fuel costs per ton-mile and passenger-mile followed the same pattern of efficiency.

Faced with continued high or increasing fuel prices or carbon legislation, the demand for Alaska Railroad transportation services could potentially increase with shifts away from trucking. However, because the distance from Anchorage to Fairbanks is relatively short, freight handling would have to be quite efficient and wages competitive to compete with the comparative efficiency of truck transportation, with its fewer freight intermodal transfers.

We also found that between 2008 and 2010, employment in Alaska in the transportation and warehousing industry sector declined by approximately 10%. Air transportation employment declined by 15%, with scheduled airfreight transportation employment declining by 42%. Truck transportation employment declined by 15%, and water transportation employment expanded by 30%.

To connect transportation costs to the Alaska economy, we examined a number of factors including an assessment of the most transportation-intensive industries. The industries that are most dependent on transportation services, and thus more sensitive to changes in transportation costs, are:

1. Seafood product preparation and packaging
2. Support activities for oil and gas operations
3. Transport by truck
4. Drilling of oil and gas wells
5. Construction of new nonresidential commercial and health care structures
6. Construction of new residential single-/multi-family housing
7. Electric power generation, transmission, distribution
8. Mining of gold, silver, and other metal ore
9. Food services and drinking places
10. Other state and local government enterprises

As a result, these industries are the most impacted by increases in fuel prices or other impacts that raise the cost of transportation services as an input in their production. Most of these are core industries in the Alaska economy, so any impacts to these industries would have broad consequences.

Similarly, we looked at the Alaska industries that would be most affected by carbon emissions legislation. These industries are:

1. Petroleum refineries
2. Natural gas distribution
3. State and local government electric use
4. Asphalt paving mixture and block manufacturing
5. State and local government passenger
6. Other basic chemical manufacturing
7. Transport by pipeline
8. Plastics material and resin manufacturing
9. Commercial fishing
10. Transport by air

These are also the industries that could have the most payback from increased efficiencies and reduced dependence on fossil fuels in terms of avoiding potential emission tax impacts.

Because of the fuel and carbon intensity of air transportation, there has been sustained improvement in air transportation efficiency, with increased load factors and increased fuel efficiency of airplanes. Of the four transportation sectors analyzed, air transportation is the most vulnerable to emissions legislation impacts.

Alaska households at all income levels are also vulnerable to increases in the price of transportation services as a result of fuel price increases or carbon emissions legislation. If Alaska households continued to purchase transportation services at the same level after fuel price increases similar to those that occurred between 2008 and 2010, these services would cost an additional $26.8 million; an estimated 73% of these cost increases would be paid by households earning over $50,000 annually because they are more able to absorb these higher costs. In all likelihood, however, households would reduce their expenditures on transportation services. Water and truck transportation services declined the most in our simulation, probably because the majority of routine purchases of goods by Alaska households are transported by water and truck.

In addition to the higher cost of transportation services resulting from increases in fuel prices, direct purchases of refined petroleum products by Alaska households would cost an additional $124.1 million, if households continued to purchase at the same level after the kinds of fuel price increases experienced between 2008 and 2010. Similar to transportation services price increases, an estimated 70% of the refined petroleum price increases would be absorbed by households with incomes of $50,000 or higher.

Our economic impact simulation did not include utilities, so price increases for space heating and electricity are not included in these estimates.

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Appendix A. Marine Transportation Companies

Marine Ships

Totem Ocean Trailer Express (TOTE, Inc.) is an Alaska-based transportation company offering marine and land transportation services between Alaska and the contiguous U.S. states. TOTE's service offering includes both marine and highway services operating between Tacoma, Washington and Anchorage, Alaska (TOTE, 2012).

TOTE operates a twice-weekly northbound and southbound service between Tacoma and Anchorage. The marine service is a roll on-roll off service for highway trailers and automobiles. The ORCA and Ponce class vessels have trailer capacities of 600 and 380 forty-foot equivalent units (FEU), respectively. Transit time between Tacoma and Anchorage ranges from 66 to 72 hours in each direction over a sailing distance of 1,450 nautical miles.

Horizon, Inc., based in Charlotte, North Carolina, is the United States' leading Jones Act container shipping and logistics company, accounting for approximately 37% of the total U.S. marine container shipments between the continental U.S. and the three noncontiguous Jones Act markets of Alaska, Hawaii, and Puerto Rico. In 2003 the Carlyle Group, a global private equity firm, purchased the Horizon Services Group of CSX Lines and renamed it Horizon Lines LLC.

Horizon operates twice-weekly service from Tacoma directly to Anchorage with a follow-on call to the Port of Kodiak. One vessel per week then makes a call at Dutch Harbor. Truck and barge services connect these three principal destination ports with surrounding locations including Akutan, Bristol Bay, the Pribilof Islands, King Cove, Sand Point, the Kenai Peninsula, Prudhoe Bay, Eagle River, Fairbanks and Palmer. Transit time between Tacoma and Anchorage is approximately three and one-half days (Horizon, 2012).

Barges

Lynden Inc. is the parent company of a family of transportation and logistics companies primarily serving Alaska and the Pacific Northwest. Lynden companies provide multi-modal transportation services including air, marine, and land services to, from, and within Alaska. Key transportation companies under the Lynden Group include:

Alaska Marine Lines

Alaska Marine Lines (AML) provides twice per week barge services between Seattle and Southeast Alaska. The Southeast Alaska barge services a number of locations including Juneau, Ketchikan, Petersburg, Sitka, and Kake. AML barge services handle full container, less than container, refrigerated, and break bulk cargo. Principal customers consist of retail establishments such as grocery outlets.

AML also services the Central Alaska market with weekly barge service between Seattle and Anchorage with overland connections to Seward, Kenai, and Fairbanks.

Alaska West Express

Alaska West Express (AWE) provides truckload transportation throughout the United States and Canada, specializing in shipments to and from Alaska. Alaska West Express is a leader in transporting liquid and dry-bulk products, hazardous and nonhazardous chemicals and petroleum products. AWE operates a rail terminal at Fairbanks, offering product transfer services for liquid and dry bulk products serving primarily the oil and gas industry.

Lynden Transport

Lynden Transport is a complete multi-modal, regional, common and contract carrier primarily serving Alaska. Lynden Transport also provides LTL cargo service on motor-water-motor routes using steamships, barges, and ferries. Lynden Transport has truckload capabilities for dry van, refrigerated, flatbed and heavy-haul commodities on both water and highway routes.

Alaska Railbelt Marine (ARM) operates scheduled, once per week railcar barge service between Seattle and Whittier, Alaska. This service operates in partnership with the Alaska Railroad providing freight service to Southcentral Alaska. ARM operates the service using three rail barges with estimated railcar capacities of 40 cars each plus deck space for bulk and container cargo.

CN AquaTrain

CN AquaTrain, operated by Foss Maritime, provides marine services for railcar movements between Alaska and Canada and the Lower 48.[2] The service operates one of the world's largest railcar barges, accommodating 45 railcars on 8 tracks. The service is integrated with CN Rail's North American network and services shippers of bulk products serving the Alaska market principally with industrial commodities such as fertilizers, sand, methanol, salt, lumber, and petroleum products. The CN AquaTrain service connects to the Alaska Railroad at Whittier for rail delivery to inland points. Transit time over the 830 nautical mile voyage is approximately four days.

CN AquaTrain operates an average of 35 barge sailings per year from Prince Rupert, British Columbia, to Whittier, Alaska. With a nominal barge capacity of 45 railcars per sailing, its estimated total annual movements are in the order of 1,575 railcars per year. Based on an average per car payload of 92 tons per railcar, we estimate that CN's AquaTrain service can transport approximately 145,500 short tons of freight into the Alaska market annually.

[2] Foss Maritime was purchased by Saltchuk Resources in 1987. Saltchuk is also the parent company of Totem Ocean Trailer Express.

Appendix B. Barge Fuel Use Calculations

In contrast to other modes where we received considerable information from a number of companies or the data were public through reporting requirements, only one barge company provided monthly data for the movement of freight. We used this barge company's data as a prototype to construct a barge fuel use model. The prototype barge company's information was expanded to include additional barge trips by travel segments based on U.S. Army Corps of Engineers published Waterborne Statistics of freight movement by port (U.S. Army Corps of Engineers, 2012a, b) and published freight schedules of barge companies serving Alaska (company websites, Northern Economics, 2006).

Scheduled Barge Traffic

For scheduled barge service, we used the number of trips posted on company websites and other sources to calculate an estimated number of barge miles to the Southcentral, Southeast, and Western regions of Alaska as described below.

Southcentral Alaska

For this calculation, we used number of trips between Anchorage-Seattle and Whittier-Seattle. This number of trips was multiplied by 3,000, the Anchorage-Seattle / Whittier-Seattle distance traveled provided by the prototype barge company. Some of the trips between Anchorage-Seattle also include additional travel to Western Alaska, so to avoid double counting, 1,500 miles was subtracted for every trip to Western Alaska that stopped in Anchorage. This was the same methodology used for trips to Western Alaska that the prototype barge company provided in their calculations.

$$\text{Nautical Miles to Southcentral Alaska} = (w * 3{,}000) + (a * 3{,}000) - (W * 1{,}500)$$

w = # of trips to Whittier

a = # of trips to Anchorage

W = # of trips to Western Alaska

Southeast Alaska

For the calculation of the number of miles traveled by the prototype barge company to Southeast Alaska, we started with number of trips then multiplied by 1,770, the provided number of miles. This was adjusted, as appropriate, for any trips that are shared with other barge companies.

$$\text{Nautical Miles to Southeast Alaska} = (SE * 1{,}770)$$

SE = # of trips to Southeast Alaska

Western Alaska

Western Alaska trips reflected the seasonal closure by Bering Sea ice and incorporated the other portion of miles from a trip with an Anchorage link. For the months of October to February, we multiplied the number of trips per month by 5,000, in March by 6,000, and during the months of April to September by 6,800, reflecting the data provided by the prototype barge company.

If from October through February

Nautical Miles to Western Alaska = (W * 5,000) – (a *1,500)

If in March

Nautical Miles to Western Alaska = (W * 6,000) – (a *1,500)

If from April through September

Nautical Miles to Western Alaska = (W * 6,800) – (a *1,500)

a = # of trips to Anchorage

W = # of trips to Western Alaska

Unscheduled Barge Traffic

Kivalina

The Port of Kivalina is unique in Western Alaska because of the nearby Red Dog mine, which is included in the Kivalina data in U.S. Army Corps of Engineers, Waterborne Statistics port information. For example, nearly three million short tons were exported in 2010, making it (by tonnage) the second largest exporting port in Alaska.[3] Due to the shallow nature of the port, numerous trips are made to lighter materials by barge to approximately 5 miles offshore to transfer ore to larger cargo ships and to transport fuel needed for the mine's operation. Another characteristic of Kivalina is the short window that vessels can navigate the Bering Sea, giving roughly four months to perform all this needed shipping.

To calculate the nautical miles traveled by tug to service Kivalina, we used the total number of barges that left the port and multiplied this by the estimated 10 miles traveled to lighter to the barge and return. Due to seasonal ice constraints, it is assumed that efforts to transfer materials would be evenly distributed across the months of June through September.

Liquid Barge Traffic

Several assumptions were needed to calculate liquid barge traffic in Alaska. Since we had data from waterborne statistics on the number of vessels that departed and received at a port but no way to identify the exact route, we assumed that the supply chain for Alaska was based on a three-stage system. An example of this process is as follows: first stage we assumed was refinery to hub, second stage was hub to sub-hub, and the third stage was sub-hub to communities. The third stage is the least-observable stage because of the limits of the available public data and the proprietary nature of the data. If one of these stages was skipped because it was more economical to service directly to a community, that would not be observable for the same reason that the third stage is not observable.

[3] U.S. Army Corps of Engineers, Waterborne Commerce Statistics, Pacific Coast, Alaska, 2012.

To calculate the distances traveled, we used the NOAA distance table[4] when possible or extrapolated distance combining the NOAA distance and the distance provided by the prototype barge company (NOAA, 2012).

Valdez – Anchorage

As a first stage in the supply chain, we assumed fuel from the refinery in Valdez was shipped directly to Anchorage. For the quantity of trips in this route we used the total number of liquid barges that departed from Valdez and assumed each barge was an individual trip with a single tug with each barge. For distance, we used the distance provided by the National Oceanic and Atmospheric Association (NOAA) in its published port-to-port distances (NOAA, 2012). The distribution of trips is again based on the prototype barge company's seasonal distribution for Southcentral Alaska.

Anchorage – Unalaska

This is an example of a second stage, where Unalaska is seen as a sub-hub to Western Alaska. The quantity of liquid barges received at Unalaska is assumed to be each a single trip between Unalaska and Anchorage, and the distance is based on the data provided by the prototype barge company.

Unalaska – Western Alaska

Because of the lack of information about supplying in this region, we used the distance provided by the prototype barge company data and the number of trips from waterborne statistics. For the number of trips, we used the number of liquid barges that left Unalaska, and for the schedule, we used the seasonal ice-free distribution of trips for Western Alaska by the prototype barge company. For the distance, we used the difference between 5,000 (distance from Dutch Harbor to Seattle) and 6,800 (assumed distance from Seattle to Western Alaska). This resulted in a calculated 1,800 nautical miles per trip to supply liquid fuels to the coast of Western Alaska from Unalaska/Dutch Harbor. These calculations are meant to capture both the second and third stage in our supply chain model.

Anacortes, Washington – Southeast Alaska

For this calculation, we used the distance the prototype barge company provided to service Southeast Alaska and subtracted the distance between Tacoma, Washington, and Anacortes, Washington. For the number of trips, we used the number of liquid barges making deliveries to Ketchikan, the major fuel hub for this region, shown in Waterborne Statistics. We assume that the additional trips needed to service the other communities in the region are captured by the miles provided by the prototype company.

Final Calculations

Marine Service

After constructing the model of the number of nautical miles traveled in transporting barges by tug, we then had to calculate fuel usage for these trips. For these calculations we used the figures provided by the prototype barge company for daily fuel usage by region. They also used the average speed of 7.5 nautical miles per hour in their calculations. Given the lack of information provided by other barge

[4] Distance Between United States Ports - http://www.nauticalcharts.noaa.gov/nsd/distances-ports/distances.pdf

companies, we had to assume that the prototype barge company's tugs were sufficiently similar in operation and condition.

The prototype barge company gave a different fuel usage per day for each region. For Southeast Alaska they provided 3,000 gallons per day, for Southcentral Alaska they provided 3,800 gallons per day, and for Western Alaska they provided 4,500 gallons per day. We believe these figures incorporate the additional fuel usage for tugs having to idle for proper tide levels to offload, varying ocean conditions, and the variation in the fleet for each region.

With the average of 7.5 nautical miles per hour, we calculated the number of hours and then the number of days traveled per month to service each region. Taking the number of days traveled by region, we used the daily fuel usage figures provided by the prototype barge company to calculate the total fuel usage in each region.

Inland Waterways

The process we followed for estimating inland barge traffic was based on a combination of Waterborne Statistics, U.S. Census Data, and expert input. The major rivers we were concerned with in these calculations were the Kuskokwim and the Yukon Rivers, given the significant populations along or near their banks and the amount of supply required to support these communities.

The calculations began with the 2010 U.S. Census Data, which was then combined with the approximation that 1.8 to 2.7 tons of petroleum is required per person in Western Alaska (Northern Economics, 2006). With these two figures, we calculated the petroleum needed for each community along the Yukon and Kuskokwim Rivers. We used the upper end of the per capita estimate in part to also capture the additional transportation for other supplies.

Given the heterogeneity of both the vessels that operated along these waterways and the conditions along these waterways, we had to make simplifying assumptions for our calculations.

An important assumption we made was for a prototype tug and barge set. The purpose of this was to combine observation of ships listed on inland waterway ports[5] and expert information into a simplified form for making equal calculations across these waterways. Our prototype tug and barge set consisted of a tug with 1,500 horsepower transporting four barges capable of safely transporting 120,000 gallons[6] or roughly 1,720 short tons per sailing. Another assumption made for operating conditions was an average operating speed of four knots, and average operational level at 66% of maximum horsepower. Under these assumptions we calculated fuel usage based on 40 gallons per 1,000 horsepower per hour. We were informed that barge service along the river systems operates under the process of supplying each community as the barge reaches it; the barge then proceeds along the river until it is empty. Using the prototype tug and barge set with the expert information, we used two modified methods for calculating transportation on each of the river systems.[7]

[5] U.S. Army Corps of Engineers, Waterborne Transportation Lines of the Unites States 2010
[6] Conversion: 1 short ton ~ 279 gallons, Source: *U.S. Geological Survey Digital Data Series*
[7] Several of these assumptions are based on information provided by Mark Smith, Vitus Marine

Service to communities along the Yukon River originates from one of two points: Communities upstream of Pilot Station are serviced from the city of Nenana; all other communities including Pilot Station are serviced through the mouth from a source along the ocean.[8] But because the Nenana River joins the Yukon River at Tanana and there is a significant population upstream from this junction, we separated these communities into two groups, with the river junction being the dividing point.[9] With the communities sectioned into three categories, the number of trips needed to service them was calculated based on the assumed tug and barge set described above. The distance to the communities was found by combining distances from NOAA,[10] with estimates found by string measurement using Google Earth.

The calculations for servicing communities along the Kuskokwim River were very similar to those described in servicing the Yukon River. We started by dividing the river into three sections. Since services for these communities are based largely out of the city of Bethel, the communities were divided based on their distance from Bethel. The first section was for all those communities within 50 nautical miles of Bethel. With the population of Bethel, these communities make up nearly 85% of the population along the Kuskokwim River. The second section was those communities between 50 to 100 nautical miles, and the third section was all remaining communities greater than 100 nautical miles from Bethel. We then calculated the number of trips based on the total trips needed from the prototype tug and barge set to service each section. For total distance traveled we multiplied the maximum distance traveled to service a section by the total trips found. The distances for these calculations were all based on string measurement using mapping software.

$$\text{Fuel usage} = (D/\ 4\ \text{knots}) * (HP) *((40\ \text{Gallons/hour})/\ 1000\ HP)$$

D = Distance traveled in Nautical Miles

HP = Average Operational Horsepower

Limitation of the Analysis

Lack of Inland Traffic Data

Because of the lack of public data on barge traffic on inland waterways, we had to estimate based on a combination of assumptions, expert references, and calculations using inferred information.

Minor Traffic

A concern that exists in all these estimates is the lack of data on third-stage distribution and any other minor barge traffic to specific communities. Many communities had no data available through U.S. Waterborne Statistics. Communities that did have data lacked unique identification, which made the risk of double counting an issue. In an effort to avoid double counting, we likely estimated too low rather than too high.

[8] Based on information provided by Vitus Marine

[9] All communities that are along the Yukon River but have road access were excluded because of the availability of trucks to supply them.

[10] Distance Between United States Ports - http://www.nauticalcharts.noaa.gov/nsd/distances-ports/distances.pdf

Appendix C. Data Dictionary of Variables and Sources Used for Aviation Fuel Estimates

Name **Source** **Description**

FREIGHTenter BTS - T100 Freight in lbs on unscheduled flights coming into Alaska from outside Alaska

FREIGHTenter_s BTS - T100 Freight in lbs on scheduled flights coming into Alaska from outside Alaska

FREIGHTexit BTS - T100 Freight in lbs on NON-scheduled flights exiting Alaska

FREIGHTexit_s BTS - T100 Freight in lbs on scheduled flights exiting Alaska

FREIGHTintra BTS - T100 Freight in lbs on NON-scheduled intra-Alaska flights

FREIGHTintra_s BTS - T100 Freight in lbs on scheduled intra-Alaska flights

MAILenter BTS - T100 Mail in lbs on NON-scheduled flights coming into Alaska from outside Alaska

MAILenter_s BTS - T100 Mail in lbs on scheduled flights coming into Alaska from outside Alaska

MAILexit BTS - T100 Mail in lbs on NON-scheduled flights exiting Alaska

MAILexit_s BTS - T100 Mail in lbs on scheduled flights exiting Alaska

MAILintra BTS - T100 Mail in lbs on NON-scheduled intra-Alaska flights

MAILintra_s BTS - T100 Mail in lbs on scheduled intra-Alaska flights

MILESenter BTS - T100 Sum of miles in between all segments of NON-scheduled flights originating outside Alaska with a destination in Alaska. This is NOT equal to the distance flown, but rather the distance between all the segments. If a flight had 3 trips between Seattle and Anchorage, the distance shown in miles would be the distance between Seattle and Anchorage instead of three times the distance between Seattle and Anchorage.

MILESenter_s BTS - T100 Sum of miles in between all segments of scheduled flights originating outside Alaska with a destination in Alaska. This is NOT equal to the distance flown, but rather the distance between all the segments. If a flight had 3 trips between Seattle and Anchorage, the distance shown in miles would be the distance between Seattle and Anchorage instead of three times the distance between Seattle and Anchorage.

MILESexit BTS - T100 Sum of miles in between all segments of NON-scheduled flights exiting Alaska with a destination outside Alaska. This is NOT equal to the distance flown, but rather the distance between all the segments. If a flight had 3 trips between Anchorage and Seattle, the distance shown in miles would be the distance between Seattle and Anchorage instead of three times the distance between Seattle and Anchorage.

MILESexit_s BTS - T100 Sum of miles in between all segments of scheduled flights exiting Alaska with a destination outside Alaska. This is NOT equal to the distance flown, but rather the distance between all the segments. If a flight had 3 trips between Anchorage and Seattle, the distance shown in miles would be the distance between Seattle and Anchorage instead of three times the distance between Seattle and Anchorage.

MILESintra BTS - T100 Sum of miles in between all segments of NON-scheduled flights within Alaska. This is NOT equal to the distance flown, but rather the distance between all the segments. If a flight had 3 trips between Fairbanks and Anchorage, the distance shown in miles would be the distance between Fairbanks and Anchorage instead of three times the distance between Fairbanks and Anchorage.

MILESintra_s BTS - T100 Sum of miles in between all segments of scheduled flights within Alaska. This is NOT equal to the distance flown, but rather the distance between all the segments. If a flight had 3 trips between Fairbanks and Anchorage, the distance shown in miles would be the distance between Fairbanks and Anchorage instead of three times the distance between Fairbanks and Anchorage.

PAXenter BTS - T100 Passengers on NON-scheduled flights coming into Alaska from outside Alaska

PAXenter_s BTS - T100 Passengers on scheduled flights coming into Alaska from outside Alaska

PAXexit BTS - T100 Passengers on NON-scheduled flights exiting Alaska

PAXexit_s BTS - T100 Passengers on scheduled flights exiting Alaska

PAXintra BTS - T100 Passengers on NON-scheduled intra-Alaska flights

PAXintra_s BTS - T100 Passengers on scheduled intra-Alaska flights

NALAcost BTS - P12A Nominal fuel cost of NON-scheduled intra-Alaska flights

NALAcost_real author calc. Inflation adjusted NALA_cost using the U.S. CPI as shown at: http://labor.alaska.gov/research/cpi/cpi.htm and converting to 2011 U.S. $

NALAgallons BTS - P12A Fuel consumption of NON-scheduled intra-Alaska flights

SALAcost BTS - P12A Nominal fuel cost of scheduled intra-Alaska flights

SALA_cost_real author calc. Inflation adjusted SALA_cost using the U.S. CPI as shown at: http://labor.alaska.gov/research/cpi/cpi.htm and converting to 2011 U.S. $

SALAgallons BTS - P12A Fuel consumption of scheduled intra-Alaska flights

FUEL EIA SEDS Transportation sector fuel consumption of aviation gas and jet fuel in gallons, equal to fuel consumption of intra-Alaska flights and flights exiting Alaska. Originally, these data were annual and av-gas and jet fuel were summed. I reallocated based on seasonality observed in intra-Alaska fuel consumed on scheduled and non-scheduled flights.

Note, through 2004, the EIA data includes kerosene-type (Jet A) and naphtha-type (Jet B) jet fuel. Beginning in 2005, data only include kerosene-type jet (A) fuel. Naphtha-type jet fuel, which is used by the military, is included in EIA SEDS "Industrial sector, Other Petroleum."

Note, fuel consumption by the military is not included in the BTS data.

FUELcost EIA Transportation sector fuel cost of aviation gas and jet fuel in gallons equal to fuel costs related to intra-Alaska flights and flights exiting Alaska. Just like the data on fuel (see above), these data are aggregated into annual numbers. Since we have much more granular data for aviation, it makes sense to use the best available data we have, so for intra-Alaska flights, we use the monthly fuel price information. Since the entering and exiting fuel quantities are estimates based on EIA SEDS estimates, it seems like it would be reasonable to use the annual fuel price figures that accompany that data. Otherwise, the effort required to produce precision in fuel quantity data may not be supported.

FUELcost_real author calc. The product of FUELcost and an annual average price calculated in sheet: EIA_SEDS_fuel_cost inflation adjusted using the U.S. CPI as shown at: http://labor.alaska.gov/research/cpi/cpi.htm and converting to 2011 U.S. $

CONFIG (Aircraft configuration)

Code	Description
0	Aircraft Configuration Not Relevant
1	Passenger Configuration
2	Freight Configuration
3	Combined Passenger and Freight on a main deck
4	Seaplane
9	Used for capturing expenses not attributed to specific aircraft types

CLASS (service class)

Note, highlighted are the classes observed in the data

Code	Description
A	Scheduled First Class Passenger/ Cargo Service A
C	Scheduled Coach Passenger/ Cargo Service C
E	Scheduled Mixed First Class and Coach, Passenger/ Cargo Service E
F	Scheduled Passenger/ Cargo Service F
G	Scheduled All Cargo Service G
H	Humane Reason Unscheduled, Non-Revenue-Generating
K	Scheduled Service K (F+G)
L	Non-Scheduled Civilian Passenger/ Cargo Service L
N	Non-Scheduled Military Passenger/ Cargo Service N
P	Non-Scheduled Civilian All Cargo Service P
Q	Non-Scheduled Services (Other Than Charter) Q
R	Non-Scheduled Military All Cargo R

V	Non-Scheduled Service V (L+N+P+R) For U.S. Carrier and (L+P+Q) For Foreign Carrier
Z	All Service Z (K+V)

Table C1. Fuel usage and costs for intra-state scheduled air transportation in Alaska 2005-2010, 2011$

		Scheduled intra-state					
		2005	2006	2007	2008	2009	2010
Fuel data							
Total reported fuel consumption [gallons]		32,256,258	32,654,457	30,684,229	31,457,698	27,330,122	27,846,200
Total reported fuel cost [2011$]		$70,049,491	$80,488,158	$79,832,197	$103,765,976	$55,388,981	$69,842,835
Reported average price [$/gal]		$2.17	$2.46	$2.60	$3.30	$2.03	$2.51
T100 segment data							
1 Passenger flights	Passengers	2,268,370	2,252,414	2,508,783	2,419,234	2,129,342	2,007,724
	Freight [short tons]	19,425	17,897	18,160	14,318	15,334	15,755
	Mail [short tons]	31,569	29,925	32,897	32,516	32,562	33,967
	Total weight [short tons]	277,831	273,063	301,935	288,757	260,830	250,495
	Distance [statute miles]	30,471,202	29,325,912	31,514,108	31,054,248	28,970,104	27,262,634
	Fuel [gallons]	17,469,905	17,368,112	17,461,721	17,146,127	14,954,123	14,032,350
	Fuel cost[$2011]	$37,938,620	$42,809,695	$45,430,751	$56,558,005	$30,306,985	$35,195,434
2 Cargo flights	Passengers	1,279	1,153	83	-	9	-
	Freight [short tons]	61,067	60,524	64,613	63,674	54,787	57,504
	Mail [short tons]	65,252	65,279	63,679	63,781	59,005	58,621
	Total weight [short tons]	126,447	125,918	128,300	127,454	113,793	116,125
	Distance [statute miles]	10,044,037	9,735,366	10,414,435	10,299,871	10,053,010	10,046,743
	Fuel (gallons)	7,950,910	8,009,018	7,419,954	7,568,123	6,524,065	6,505,137
	Fuel cost	$17,266,640	$19,740,985	$19,304,746	$24,964,116	$13,222,089	$16,315,950
3 Mixed flights	Passengers	656,059	728,181	607,596	700,017	625,298	905,776
	Freight [short tons]	17,177	17,108	16,056	18,844	19,434	20,494
	Mail [short tons]	19,873	19,189	16,590	17,187	13,497	13,050
	Total weight [short tons]	102,656	109,116	93,406	106,032	95,461	124,121
	Distance [statute miles]	11,994,249	12,525,908	10,512,191	10,158,530	7,908,228	10,145,191
	Fuel (gallons)	6,454,955	6,940,278	5,401,903	6,296,086	5,473,034	6,953,071
	Fuel cost	$14,017,940	$17,106,705	$14,054,314	$20,768,191	$11,092,002	$17,439,442
4 Seaplane	Passengers	42,824	34,509	49,308	56,515	47,347	44,837
	Freight [short tons]	491	542	631	595	621	625
	Mail [short tons]	1,278	1,307	1,366	1,287	1,253	1,239
	Total weight [short tons]	6,051	5,299	6,928	7,534	6,609	6,349
	Distance [statute miles]	824,276	789,645	923,078	983,336	968,210	987,847
	Fuel (gallons)	380,489	337,049	400,650	447,362	378,901	355,642
	Fuel cost	$826,291	$830,773	$1,042,385	$1,475,664	$767,904	$892,009

Notes: Numbers in black are directly from the BTS and EIA data. Blue numbers were calculated from BTS and EIA data. Total weight includes freight, mail and passengers. Aircraft type numbers are T100 data codes.
Sources: U.S. DOT, BTS; U.S. DOE, EIA; FAA; author calculations.

TableC2. Fuel usage and costs for intra-state non-scheduled air transportation in Alaska 2005-2010, 2011$

		Non-scheduled intra-state					
		2005	2006	2007	2008	2009	2010
Fuel data							
Total reported fuel consumption [gallons]		1,463,625	1,388,093	5,963,125	9,301,368	6,732,250	7,859,375
Total reported fuel cost [2011$]		$3,435,273	$3,587,177	$17,190,711	$32,761,806	$16,001,674	$17,258,454
Reported average price [$/gal]		$2.35	$2.58	$2.88	$3.52	$2.38	$2.20
T100 segment data							
1 Passenger flights	Passengers	127,981	119,216	126,166	103,532	106,563	105,223
	Freight [short tons]	1,794	1,559	1,937	1,214	1,174	1,283
	Mail [short tons]	10	13	42	25	62	68
	Total weight [short tons]	14,602	13,494	14,596	11,592	11,893	11,873
	Distance [statute miles]	3,543,858	3,468,474	3,758,337	3,243,212	3,445,972	3,521,271
	Fuel [gallons]	537,512	462,930	1,582,156	2,982,032	2,298,728	2,505,250
	Fuel cost[$2011]	$1,261,594	$1,196,325	$4,561,097	$10,503,484	$5,463,774	$5,501,295
2 Cargo flights	Passengers	1	-	20	-	-	-
	Freight [short tons]	16,099	18,103	31,648	16,473	14,428	16,246
	Mail [short tons]	518	317	74	56	142	23
	Total weight [short tons]	16,617	18,420	31,724	16,529	14,570	16,269
	Distance [statute miles]	1,154,873	892,210	901,922	561,937	472,310	590,498
	Fuel (gallons)	611,704	631,938	3,438,809	4,251,946	2,816,141	3,432,777
	Fuel cost	$1,435,730	$1,633,084	$9,913,522	$14,976,444	$6,693,596	$7,538,058
3 Mixed flights	Passengers	32,977	37,401	35,311	34,240	36,658	43,049
	Freight [short tons]	1,692	1,798	1,492	1,251	1,184	1,101
	Mail [short tons]	36	42	35	27	21	20
	Total weight [short tons]	5,026	5,580	5,059	4,702	4,871	5,426
	Distance [statute miles]	1,087,000	1,116,981	1,145,982	971,469	922,759	1,077,665
	Fuel (gallons)	185,025	191,446	548,348	1,209,643	941,458	1,144,939
	Fuel cost	$434,272	$494,745	$1,580,796	$4,260,672	$2,237,723	$2,514,180
4 Seaplane	Passengers	34,982	28,852	35,947	32,435	34,386	36,236
	Freight [short tons]	16	81	38	87	56	53
	Mail [short tons]	1	1	-	4	2	3
	Total weight [short tons]	3,515	2,967	3,633	3,334	3,497	3,680
	Distance [statute miles]	133,947	111,134	204,976	170,635	123,687	110,298
	Fuel (gallons)	129,384	101,780	393,812	857,747	675,923	776,409
	Fuel cost	$303,676	$263,024	$1,135,295	$3,021,207	$1,606,580	$1,704,922

Notes: Numbers in black are directly from the BTS and EIA data. Blue numbers were calculated from BTS and EIA data. Total weight includes freight, mail and passengers. Aircraft type numbers are T100 data codes.
Sources: U.S. DOT, BTS; U.S. DOE, EIA; FAA; author calculations.

Table C3. Fuel usage and costs for exiting scheduled and non-scheduled air transportation in Alaska 2005-2010, 2011$

		Exiting (scheduled & nonscheduled)					
		2005	2006	2007	2008	2009	2010
Fuel data							
Total reported fuel consumption [gallons]		1,319,394,117	1,309,831,450	1,193,994,646	967,954,934	762,383,628	925,632,425
Total reported fuel cost [2011$]		$2,697,422,794	$2,994,219,343	$2,856,751,124	$3,063,036,030	$1,427,105,264	$2,169,344,617
Reported average price [$/gal]		$2.04	$2.29	$2.39	$3.16	$1.87	$2.34
T100 segment data							
1 Passenger flights	Passengers	2,189,746	2,154,740	2,195,794	2,032,243	1,815,705	1,865,517
	Freight [short tons]	22,171	17,123	17,166	11,891	13,605	13,663
	Mail [short tons]	265	401	360	305	279	204
	Total weight [short tons]	241,411	232,999	237,105	215,421	195,454	200,419
	Distance [statute miles]	33,510,436	31,287,722	30,879,363	29,058,494	25,152,916	26,741,639
	Fuel [gallons]	101,982,850	93,977,168	87,607,285	78,195,517	68,502,012	69,581,079
	Fuel cost[$2011]	$208,497,870	$214,827,835	$209,609,155	$247,445,081	$128,228,858	$163,072,656
2 Cargo flights	Passengers	0	0	0	0	0	0
	Freight [short tons]	2,870,685	3,007,132	2,986,227	2,442,106	1,972,402	2,457,062
	Mail [short tons]	7,663	6,393	4,412	3,881	2,376	3,797
	Total weight [short tons]	2,878,348	3,013,525	2,990,639	2,445,987	1,974,778	2,460,859
	Distance [statute miles]	137,047,042	142,574,848	137,020,314	111,727,133	87,638,070	108,131,950
	Fuel (gallons)	1,215,943,618	1,215,468,698	1,105,002,697	887,868,211	692,112,272	854,355,694
	Fuel cost	$2,485,924,402	$2,778,510,079	$2,643,829,021	$2,809,606,340	$1,295,564,372	$2,002,297,970
3 Mixed flights	Passengers	20,966	6,053	20,136	30,563	28,996	27,652
	Freight [short tons]	1,375	346	1,728	2,144	2,140	2,111
	Mail [short tons]	2	5	6	10	9	8
	Total weight [short tons]	3,474	956	3,748	5,210	5,048	4,884
	Distance [statute miles]	399,219	107,917	387,368	614,689	648,313	676,972
	Fuel (gallons)	1,467,649	385,584	1,384,665	1,891,206	1,769,344	1,695,652
	Fuel cost	$3,000,522	$881,429	$3,312,948	$5,984,609	$3,312,034	$3,973,990
4 Seaplane	Passengers	0	0	0	0	0	0
	Freight [short tons]	-	-	-	-	-	-
	Mail [short tons]	-	-	-	-	-	-
	Total weight [short tons]	-	-	-	-	-	-
	Distance [statute miles]	-	-	-	-	-	-
	Fuel (gallons)	-	-	-	-	-	-
	Fuel cost	$0	$0	$0	$0	$0	$0

Notes: Numbers in black are directly from the BTS and EIA data. Blue numbers were calculated from BTS and EIA data. Total weight includes freight, mail and passengers. Aircraft type numbers are T100 data codes.
Sources: U.S. DOT, BTS; U.S. DOE, EIA; FAA; author calculations.

Table C4. Fuel usage and costs for entering scheduled and non-scheduled air transportation in Alaska 2005-2010, 2011$

		Entering (scheduled & non-scheduled)					
		2005	2006	2007	2008	2009	2010
Fuel data							
Total reported fuel consumption [gallons]		1,341,749,279	1,318,070,401	1,207,421,777	982,127,718	772,386,783	934,194,928
Total reported fuel cost [2011$]		$2,743,126,593	$3,013,053,236	$2,888,876,874	$3,107,884,964	$1,445,830,162	$2,189,412,000
Reported average price [$/gal]		$2.04	$2.29	$2.39	$3.16	$1.87	$2.34
T100 segment data							
1 Passenger flights	Passengers	2,176,956	2,140,180	2,190,805	2,033,178	1,812,284	1,847,570
	Freight [short tons]	17,522	13,990	13,562	11,802	9,402	11,574
	Mail [short tons]	1,480	975	615	767	796	821
	Total weight [short tons]	236,698	228,984	233,257	215,887	191,427	197,152
	Distance [statute miles]	33,408,731	31,103,349	30,721,441	28,703,226	24,719,040	26,182,194
	Fuel [gallons]	99,991,701	92,357,776	86,185,405	78,364,628	67,090,646	68,446,811
	Fuel cost[$2011]	$204,427,084	$211,125,973	$206,207,167	$247,980,222	$125,586,924	$160,414,347
2 Cargo flights	Passengers	0	0	0	0	0	0
	Freight [short tons]	2,924,469	3,028,992	3,022,954	2,476,231	2,000,499	2,479,659
	Mail [short tons]	11,408	8,979	7,766	7,460	5,679	7,742
	Total weight [short tons]	2,935,876	3,037,971	3,030,720	2,483,691	2,006,178	2,487,401
	Distance [statute miles]	143,972,175	149,297,962	143,534,793	117,699,701	92,561,737	113,779,543
	Fuel (gallons)	1,240,246,158	1,225,328,509	1,119,812,037	901,554,281	703,117,216	863,570,472
	Fuel cost	$2,535,609,499	$2,801,049,191	$2,679,261,842	$2,852,915,098	$1,316,164,517	$2,023,894,047
3 Mixed flights	Passengers	21,046	6,847	21,002	33,237	31,854	33,692
	Freight [short tons]	1,426	243	1,685	2,635	2,849	2,725
	Mail [short tons]	48	25	70	126	183	179
	Total weight [short tons]	3,578	952	3,855	6,085	6,217	6,272
	Distance [statute miles]	376,726	127,135	433,438	695,035	754,264	746,330
	Fuel (gallons)	1,511,421	384,116	1,424,336	2,208,809	2,178,921	2,177,645
	Fuel cost	$3,090,010	$878,072	$3,407,865	$6,989,644	$4,078,721	$5,103,605
4 Seaplane	Passengers	0	0	0	0	0	0
	Freight [short tons]	-	-	-	-	-	-
	Mail [short tons]	-	-	-	-	-	-
	Total weight [short tons]	-	-	-	-	-	-
	Distance [statute miles]	-	-	-	-	-	-
	Fuel (gallons)	0	0	0	0	0	0
	Fuel cost	$0	$0	$0	$0	$0	$0

Notes: Numbers in black are directly from the BTS and EIA data. Blue numbers were calculated from BTS and EIA data. Total weight includes freight, mail and passengers. Aircraft type numbers are T100 data codes.
Sources: U.S. DOT, BTS; U.S. DOE, EIA; FAA; author calculations..

Appendix D. Glossary of Economic Impact Terms

Terms are presented in groups within a logical rather than an alphabetical order

Region defines the geographic area for which impacts are estimated. The region is generally an aggregation of one or more counties. In the case of this Alaska transportation analysis, the region is the state of Alaska.

Sector is a grouping of industries that produce similar products or services. Most economic reporting and models in the U.S. are based on the North American Industrial Classification system (NAIC code). The principle sectors analyzed in this report are the air, water, rail, and trucking transportation sectors.

Impact analysis estimates the impact of dollars from outside the region ("new dollars") on the region's economy.

Significance analysis estimates the importance or significance of an industry or activity to a region, usually including spending by both local residents and visitors from outside the region.

Input-output model is a representation of the flows of economic activity between sectors within a region. The model captures what each business or sector must purchase from every other sector in order to produce a dollar's worth of goods or services. Using such a model, flows of economic activity associated with any change in spending may be traced either forwards (spending generating income which induces further spending) or backwards (industry purchases of fuel that leads refineries to purchase additional inputs – crude oil, utilities, etc.). Multipliers may be derived from an input-output model.

IMPLAN is a micro-computer-based input output modeling system. With IMPLAN, one can estimate 528 sector I-O models for any region consisting of one or more counties. IMPLAN includes procedures for generating multipliers and estimating impacts by applying final demand changes to the model.

Final Demand is the term for sales to final consumers (households or government). Sales between industries are termed intermediate sales. Economic impact analysis generally estimates the regional economic impacts of final demand changes. Household spending is one type of final demand.

Direct effects are the changes in economic activity during the first round of spending. For transportation services this involves the impacts on the transportation industries (businesses selling directly to purchasers) themselves.

Secondary effects are the changes in economic activity from subsequent rounds of re-spending of transportation dollars. There are two types of secondary effects:

> **Indirect effects** are the changes in sales, income or employment within the region in backward-linked industries supplying goods and services to transportation businesses. The increased sales in truck tire supply firms resulting from more shipping services sales is an indirect effect of transportation spending.

Induced effects are the increased sales within the region from household spending of the income earned in transportation services and supporting industries. Employees in transportation services and supporting industries spend the income they earn on housing, utilities, groceries, and other consumer goods and services. This generates sales, income and employment throughout the region's economy.

Total effects are the sum of direct, indirect, and induced effects.

Multipliers capture the size of the secondary effects in a given region, generally as a ratio of the total change in economic activity in the region relative to the direct change. Multipliers may be expressed as ratios of sales, income or employment, or as ratios of total income or employment changes relative to direct sales. Multipliers express the degree of interdependency between sectors in a region's economy and therefore vary considerably across regions and sectors.

Type I multipliers measure the direct and indirect effects of a change in economic activity. Unlike Type II or SAM multipliers (discussed below), they do not include induced effects. They capture the inter-industry effects only, i.e., industries buying from local industries.

Type II multipliers capture direct and indirect effects. In addition to the inter-industry effects, the Type II multiplier also takes into account the income and expenditures of households. The household income and the household expenditures are treated as industries. This internalizes the household sector, including induced or household spending, effects.

SAM (IMPLAN Social Accounting Matrix) multipliers are similar to Type II multipliers and use all information about the institutions selected to be included in the predictive model. If only households are included, all information for industries, factors, and households are included.

A **sector-specific multiplier** gives total changes throughout the economy associated with a unit change in sales in a given sector.

Aggregate multipliers are based on some assumed initial changes in final demand. An aggregate transportation spending multiplier is based on an assumed distribution of transportation spending across economic sectors.

Capture rate is the percentage of spending that accrues to the region's economy as direct sales or final demand. All transportation spending on services within the region is captured. Generally, however, not all transportation purchases of goods are treated as final demand to the region.

Purchaser prices are the prices paid by the final consumer of a good or service. **Producer prices** are the prices of goods at the factory or production point.

For **manufactured goods** the purchaser price = producer price + retail margin + wholesale margin + transportation margin.

For **services**, the producer and purchaser prices are equivalent.

The **retail, wholesale, and transportation margins** are the portions of the purchaser price accruing to the retailer, wholesaler, and shipper, respectively. Only the retail margins of many goods purchased by transportation consumers accrue to the local region, if the wholesaler, shipper, and manufacturer lie outside the local area.

Measures of economic activity:

> **Total Industry Output (TIO)**: IMPLAN uses input/output accounting to assess the value of production by industry for a calendar year. Output can also be thought of as a value of sales plus or minus inventory.
>
> **Sales or output** is the dollar volume of a good or service produced or sold
>
> > **Final Demand** = sales to final consumers
> >
> > **Intermediate sales** = sales to other industrial sectors
>
> **Income** is the money earned within the region from production and sales. Total income includes
>
> > Wage and salary income, and
> >
> > Proprietor's income, rents and profits
>
> **Jobs** or employment is a measure of the number of jobs required to produce a given volume of sales/production. Jobs are usually not expressed as full-time equivalents, but include part-time and seasonal positions.
>
> **Value added** is the sum of total income and indirect business taxes. Value added is the most commonly used measure of the contribution of a region to the national economy, as it avoids double counting of intermediate sales and captures only the "value added" by the region to final products.

Passenger revenue ton-mile: One ton of revenue passenger weight (including all baggage) transported one mile. The passenger weight standard for both domestic and international operations is 200 pounds. (BTS5) (BTS6) http://apps.bts.gov/dictionary/search.xml